Pennsylvania Coastal Zone Management Program

NUTRIENT TRENDS AND LAND USE CHANGES IN SELECTED WATERSHEDS IN THE LOWER SUSQUEHANNA RIVER BASIN

SUSQUEHANNA RIVER BASIN COMMISSION

RESOURCE QUALITY MANAGEMENT & PROTECTION DIVISION

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ABSTRACT

Monthly water quality data from ten stations in seven watersheds of the Lower Susquehanna River Basin were analyzed for trends in total phosphorus, total ammonia-nitrogen, total nitrite-nitrogen, total nitrate-nitrogen, and total inorganic nitrogen concentrations and loads. Changes in land use activities in six counties were also investigated to make land use/nutrient trend comparisons. Based on the relationship between water quality trends and land use changes, a majority of the streams in the study area are affected by nonpoint sources of nutrients. The presence of point source contributions of nutrients is suggested where decreasing trends in total phosphorus occurred at a time of municipal sewage treatment plant (STP) installations and upgrades.

INTRODUCTION

The Chesapeake Bay Program (1982) (CBP) cites data that indicate the Bay received increased nutrient loads between 1950 and 1980. In July 1950, there were no anoxic waters and only a limited area of low dissolved oxygen (DO) in the main stem of the Bay. In the 1960's, anoxia occurred from mid-June to mid-August, while in 1980, it began during the first week in May and continued into September. This decrease in DO is believed to be caused by a concurrent increase in nutrient loading. The tributary rivers are believed to be major contributors of nitrogen and phosphorus loads to the Bay (CBP, 1982).

Purpose and Scope

The purpose of this study is to determine if and why trends in nutrient concentrations and loadings exist for tributaries in the Lower Susquehanna River Basin. This will be done for watersheds which have sufficient existing data available. The scope of this study is twofold. First, trends in nutrient concentrations and loads in the Lower Susquehanna River Basin will be assessed for the time period 1973 - 1986. Secondly, changes in land use from 1969 to 1982 in selected counties of the Lower Susquehanna River Basin will be examined to see if causal relationships between land use and nutrient concentrations and loadings can be determined.

Information about the causes for trends in nutrient loads is vital to resource managers. It is also very difficult information to obtain. Establishing causality in a definitive way is no simple matter, given the complex interactions arising from man's activities on the land. This investigation is not intended to "point the finger" at particular causes of trends, but rather to explore the nutrient trend relationships of different watersheds to changes in man's activities that may impact water quality.

In order to assess trends in water quality, knowledge of the physical features of the land and the influence of man's activities on the land is important in understanding the relationships of the processes that directly or indirectly affect water quality.

Location and Extent of Area

Location

The area discussed in this report (see Figure 1) encompasses a portion of the drainage area of the Main Stem Susquehanna River from Duncannon, Pennsylvania, downstream to the confluence of Conestoga River. The major tributaries along this reach include: Sherman Creek, Conodoguinet Creek, Yellow Breeches Creek, Swatara Creek, Conewago Creek, Codorus Creek, and Conestoga River. This portion of the basin covers an area of approximately 2,800 square miles in south-central Pennsylvania. All or most of Cumberland, Dauphin, Lancaster, Lebanon, Perry, and York Counties along with portions of Adams, Berks, Chester, Franklin, and Schuylkill Counties are included.

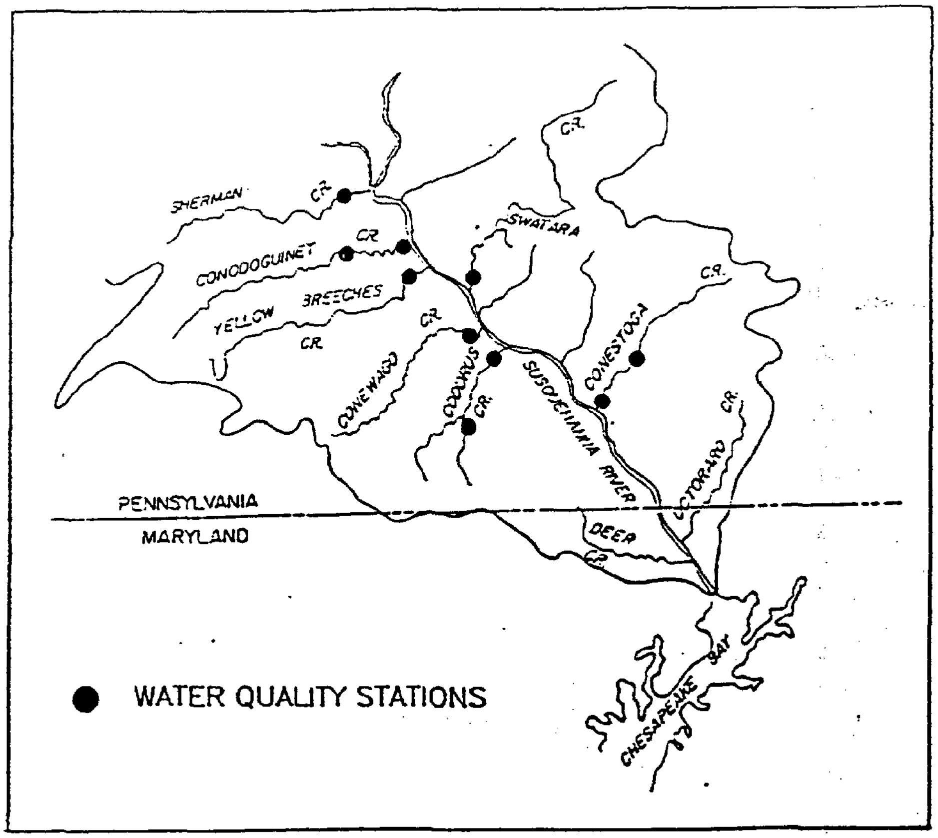

FIGURE 1. LOCATION OF STUDY AREA (WATERSHEDS)

Social and Economic Features

Population concentrations in the region are located near the geographic centers of each county. The largest cities in the subbasin, in descending order of size are Lancaster, Harrisburg, York, and Lebanon. Although south-central Pennsylvania has a significant population employed in government-related and industrial activities, agriculture is an important economic activity throughout the rural parts of the region. Some of the most productive agricultural counties in the Susquehanna River Basin are Lancaster, York, Lebanon, and Cumberland (Dept. of Environmental Resources, 1980).

Climate

The Lower Susquehanna River Basin is dominated by a Humid Continental type climate. The atmospheric conditions within the basin are primarily controlled by pressure systems traveling eastward from the Central Plains of the United States. Storms developing along the southeastern coast of the United States periodically bring moderate to heavy precipitation to the basin as moist air masses are forced upward over higher terrain.

Annual precipitation over the study area averages 41 inches. Normal monthly precipitation totals range from a minimum of 2.6 inches in February to a maximum of 4.3 inches in August (Dept. of Environmental Resources, 1980).

Terrain

The study area includes six physiographic sections (see Figure 2) resulting from a diversity of rock types and structural settings. The physiography of each section has influenced the types of soil formed in the Lower Susquehanna River Basin as described in the following paragraphs.

The northern portion of the study area lies within the Appalachian Mountain Section of the Ridge and Valley physiographic province. The soils of this section generally formed from weathered noncarbonate sedimentary rocks. Slopes vary from 3 to 35 percent with soils having a slow infiltration rate and moderate runoff.

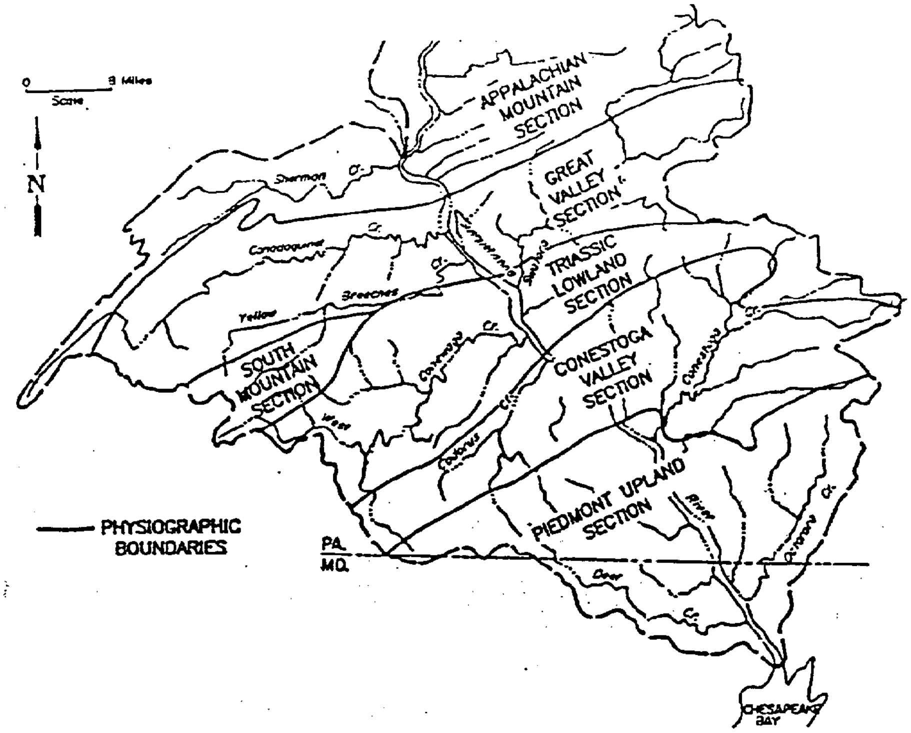

FIGURE 2 – PHYSIOGRAPHIC SECTIONS OF THE LOWER SUSQUEHANNA RIVER BASIN

The Great Valley Section of the Ridge and Valley province is south of the Appalachian Mountain Section. The Great Valley Section contains two main types of soils on slopes that vary from 0 to 25 percent. Soils in the northern portions of the valley are formed from noncarbonate shales and in the south the soils are formed from dolomites and limestones. These soils have low to moderate infiltration rates, but the rates are notably slower in the northern portion of the valley (Dept. of Environmental Resources, 1980).

The South Mountain Section of the Blue Ridge Province lies in the southwestern portion of the basin and contains some of the oldest rocks in the study area. Here, the soils are formed from igneous and metamorphic rocks, and the slopes range between 3 and 20 percent. These soils generally have a moderate infiltration rate with moderate runoff.

The Triassic Lowlands Section of the Piedmont Province contains soils that formed from red shales and sandstones locally intruded by diabase. These soils have moderate to slow infiltration rates depending on the nature of the parent material.

The region just south of the Triassic Lowlands Section is the Conestoga Valley Section. The fertile soil of this section formed from the highly folded and faulted substratum of limestone and dolomite. The presence of sinkholes and soils with moderate infiltration rates allows the surface water to quickly enter the ground water system. The 0 to 15 percent slopes in this section indicates the flatness of the terrain.

Finally, the Piedmont Uplands Section comprises the southern portion of the basin. The extremely complex structure of the metamorphosed sedimentary rocks with some igneous rocks forms the parent material of the soils in this section. These deep soils have a moderate infiltration rate with slopes of 0 to 20 percent.

Methodology

Generally, water quality data are affected by seasonal or cyclic effects, an episodic or regular effect, a long-term monotonic trend, and random noise (Bauer and others, 1984). Statistical tests aid in separating out these effects and identifying trends. Statistical tests are classified as either parametric or non-parametric. Parametric tests require knowledge of the underlying probability distribution of the random variable. Most tests assume that the variable is normally distributed. Non-parametric tests do not make any assumption about the distribution of the variable. Non-parametric techniques were utilized in this study because the underlying probability distribution of water quality variables was not known. The non-parametric test for trends utilized in this investigation is a form of Kendall's Tau (1975). A statistical procedure called the Seasonal Kendall's Tau test (Hirsch and others, 1982) was utilized to detect the presence or absence of a trend in nutrient concentrations and loads. If a trend was statistically detected, a visual inspection of the time series plot sometimes showed a monotonic or step trend. A monotonic trend in nutrient concentrations or load may be indicative of process changes in the delivery of nutrients from nonpoint sources whereas a non-monotonic trend such as a step trend may be indicative of a response from a change in point source inputs. Results of the trend analysis were then compared to historic changes in man's activities to gain a better understanding of the effect of land use activity on water quality. The procedures for determining water quality trends and land use changes are discussed below.

Water Quality Procedures

Trend analyses were performed for selected stations on tributaries of the lower Susquehanna River. The Water Quality Network (WQN) and USGS gaging stations in Pennsylvania provided the best sources of long term nutrient and discharge data. Stations selected for analysis are listed in Table 1.

TABLE 1

WATER QUALITY SAMPLING SITE LOCATION

STATION*	WATERSHED	LATITUDE/LONGITUDE
WQN0243	Sherman Creek	402249/770456
WQN0240	Conodoguinet Creek	401638/765700
WQN0213	Conodoguinet Creek	401536/770611
WQN0212	Yellow Breeches Creek	401327/765138
WQN0210	West Conewago Creek	400452/764307
WQN0207	Codorus Creek	400037/764237
WQN0209	Codorus Creek	395514/764457
WQN0205	Conestoga Creek	400300/761639
WQN0231	Conestoga Creek	395741/762158
WQN0211	Swatara Creek	401128/764352

* as identified in EPA's STORET system.

In order to analyze the data statistically, several steps were completed to review and reformat the data:

1. WQN nutrient data and USGS flow data were extracted from the data bases of the National Computer Center (NCC) for the period of 1970-1986.
2. Because the Seasonal Kendall Test requires one observation per month, multiple observations for any one

month were removed so that only one observation remained. The earliest date containing nutrient data was selected as the monthly observation, while observations later in the month were deleted.

3. If a month contained no observations, the month was ignored. Missing values do not present computational problems with the seasonal Kendall Tau test (Hirsch and Others, 1982).

4. From this 1970-1986 data set, a period of record was selected based on the completeness of data collection. For example, if nitrate data were not collected before 1973, the period of record selected for the trend analysis would be 1973-1986.

5. The parameters investigated were based on the data available in STORET and included the following:

   Phosphorus, Total (TP)
   Ammonia, Total (NH_3-N+NH_4-N)
   Nitrite, Total (NO_2-N)
   Nitrate, Total (NO_3-N)
   Nitrite + Nitrate, Total (NO_2-N+NO_3-N)
   Nitrogen, Total Inorganic (INORG-N)

After reviewing the data, time series plots and descriptive statistics of the parameters for each station were prepared. The plots permitted visual inspection of the data for obvious trends. The tables presented the magnitudes, averages, and variability of the concentration and transport (load) data. Upon completion of the plots and tables, the Seasonal Kendall trend test procedure was applied to the water quality data.

The Seasonal Kendall Test is a rank correlation test and is described in Bauer and others (1984), Hirsch and others (1982), and Smith and others (1980). It has been applied to total phosphorus data collected at stations in the National Stream Quality Accounting Network (Smith and others, 1980). Hirsch (1982) demonstrated that the testing techniques do not require complete records and that missing values or values less than the limit of detection present no computational or theoretical problem for application of the test. The Seasonal Kendall Test is different from the Kendall Test in that the test is applied to data from the same month of different years of record, thus minimizing the problem of seasonality.

The concentration and load records were checked for trends using the Seasonal Kendall Test. When a significant trend was detected for either concentration or load for any parameter, the relationship between the parameter concentration and mean daily discharge was estimated, using regression techniques and the following functions of discharge: linear (Q), logarithmic ($Log_{10}(Q)$), inverse (1/Q), and the square root ($Q^{0.5}$). The relationship which had the highest coefficient of determination was selected to determine the expected value of concentration at the mean flow value, provided that the slope of the equation was significantly different from zero at the 10% level, based on Student's t Test. Then the actual minus the expected concentration was computed using the selected equation. If the discharge-versus-concentration relationship was significant, the

Seasonal Kendall Tau procedure was applied to these flow-adjusted-concentrations (FACs) to determine whether the trends were due to trends in flow. Two different levels of significance of the relationship between concentration and discharge were defined. If the significance level, alpha, was less than 0.01, the regression was considered highly significant. If the significance level, alpha, was less than 0.1 but greater than 0.01, the relationship was considered significant.

The Seasonal Kendall Test on the residuals (FACs) determines whether it is likely that the trend in concentration is due to changes in the delivery of nutrients to the stream (point or nonpoint) or to change in flow. If the Seasonal Kendall Test on FACs shows a significant trend, the trend in either concentration or load is considered to be due to processes other than flow.

In summary, the procedure for detection of water quality trends calls for testing three time series: concentration, transport (load), and flow-adjusted-concentrations (FAC) for each station. Trends in concentration indicate probable changes in the quality of water for the period of record investigated. Trends in load indicate probable changes in nutrients being transported. Trends in FAC show whether trends in concentration or load are due to changes in streamflow, or other changes in processes which provide nutrients to the stream. Analyzing all three trends at a station can lead to a better understanding of the causes of the trends (Hirsch and Others, 1982).

Limitations of Water Quality Data

In order to reliably assess trends in water quality, data must be collected at a given location using consistent collection and laboratory techniques over a number of years (Hirsch and others, 1982, p. 107). If sampling methods or analytical techniques change over the period of record, then apparent trends in water quality may be the result of such inconsistencies rather than any change in the water quality characteristics of the stream.

Data utilized in this assessment are based on available data collected by other agencies. Limitation in the use of available data include: (1) inconsistencies of sampling techniques between various agencies results in some degree of noncomparability between data sets; (2) the short period of record at many sampling sites limits selection of stream stations; (3) important ancillary data such as stream flow were not always collected when chemical analyses were made; and (4) some stream sampling sites were not ideally located for the purposes of this study.

It would have been desirable to combine the information from the various agencies that collect water data in order to construct a more complete record of water quality. Unfortunately, the data sets could not be merged because collection techniques differed between the principal sampling agencies. There is one additional limitation in the available data. If water quality data are to represent the entire stream segment, then horizontally and vertically integrated samples are desirable. The data analyzed in this study were from grab samples which often do not adequately represent the entire cross-section of a stream.

The amount of water quality data needed for statistical analyses depends on the frequency of collection and the period of seasonality considered (Bauer, 1984, p. 10). A very short record may not contain enough data to distinguish a trend from inherent cycles in the data. The time series should cover two full cyclic periods; therefore, an absolute minimum of 24 data points would be needed to cover the seasonal effect on data collected at a monthly frequency. On the other hand, the use of long records may mask trends lasting only a few years. Smith and others (1980) used 5- to 8-year time series of data collected on a monthly frequency. Based on the above criteria a minimum record of seven years of monthly samples was decided upon. Ten stations within seven watersheds met the criteria and were selected (Table 1) for trend analysis.

Ideally, the collection of ancillary data such as instantaneous discharge at the time of sample collection is desirable so that some variations in concentration values may be explained by flow. While monthly data collection was consistent at most stations investigated in this assessment, discharge data were incomplete. Discharge data associated with the concentration record often were reported as instantaneous discharge for a short period of time, were then reported as mean daily discharge from the closest U.S. Geological Survey (USGS) station, and finally not reported at all. The only discharge data reported on a regular schedule came from USGS stations. Since USGS discharge information provided the only source of consistent flow data and was readily available in annual reports, mean daily flow data were utilized to build a transport record and incorporated in the flow-adjustment-concentration procedure.

Land Use Procedures

In order to make meaningful land use/nutrient trend comparisons and identify significant relationships, data must be collected on historic changes in man's activities that may have an influence on water quality trends. Nutrient inputs include contributions from sewage treatment plants, industrial waste discharges, and agricultural activities. Known changes in these nutrient inputs can then be compared to time-series plots of nutrient concentrations and loads from each water quality station.

An inventory of point source inputs was obtained from a treatment plant and discharge point report generated from a data base maintained by the Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management. This report provided a substantial amount of information concerning design average flow, level of treatment, location, NPDES permit number, and a sequence of waste treatment processes for industrial, municipal (public), and non-public dischargers. The sequence of waste treatment processes provided information on whether dischargers had nitrification or phosphate removal processes in operation. Municipal sewage treatment plants (STPs) installing nitrification processes in the treatment operation convert the unstable forms of nitrogen (ammonia and nitrite) to a more stable form (nitrate). Therefore, a change in nitrate-nitrogen concentrations would be expected in the stream. A reduction in phosphorus would be expected if coagulation and flocculation processes were utilized in the operation. However, the report did not provide information about treatment plant upgrades or the construction of new treatment plants. This information was retrieved from EPA's Grants Information & Control System (GICS) that listed municipal dischargers receiving grants for the construction of new wastewater treatment systems, dischargers receiving grants for modifications of existing systems, the completion dates of projects, and, sometimes, the initiation date of plant operations.

A list was compiled of industries located in each watershed. Only those types of industrial activities with the potential to discharge nutrients were identified in each watershed. The Chesapeake Bay Program (1982, p. 193-196) identified those economic activities considered to be nutrient generators and provided a list of those economic activities by the Standard Industrial Classification (SIC) system. The SIC code was utilized to locate potential nutrient generating industries in the study area. Table 2 lists the nutrient concentrations for SIC groups of industries located in the study area. The nutrient concentrations are estimates for industrial groups and may or may not apply to the specific firms listed in further sections of this report.

TABLE 2

ECONOMIC ACTIVITIES CONSIDERED
TO GENERATE NUTRIENTS*

SIC GROUP	INDUSTRY TYPE	TKN mg/l	TP mg/l
2016	Poultry Processing	7.7	
2026	Fluid Milk	61.2	10.8
2034	Dried Fruit & Vegetables	18.0	190.8
2035	Pickled Fruit & Vegetables	18.0	190.8
2077	Animal Oil Manufacturing		7.1
2813	Industrial Organic Chemicals	3.6	0.18
2879	Pesticide & Agricultural Chemicals	0.85	19.2
3411	Metal Can Manufacturing	1.15	0.35
3471	Coating, Engraving & Allied Services	1.15	0.35

TKN - Total Kjeldahl Nitrogen; TP - Total Phosphorus
*(After CBP, 1982 p. 193-196)

To compare changes in water quality parameters over time with the intensity of land use, the assumption was made that urbanization, decreases in cropland harvested, and increases in livestock populations--cattle, hogs and poultry--represented intensification of use. Under these assumptions, population trends, changes in size of the non-farm population, and information from the agricultural censuses represent changes in land use. Although information by subbasin or watershed would have been preferred, because of the available data sources used, the unit of analysis was the county. The area of interest was defined as the following counties in the Commonwealth of Pennsylvania (see Figure 3):

Adams	Lancaster
Cumberland	Perry
Dauphin	York

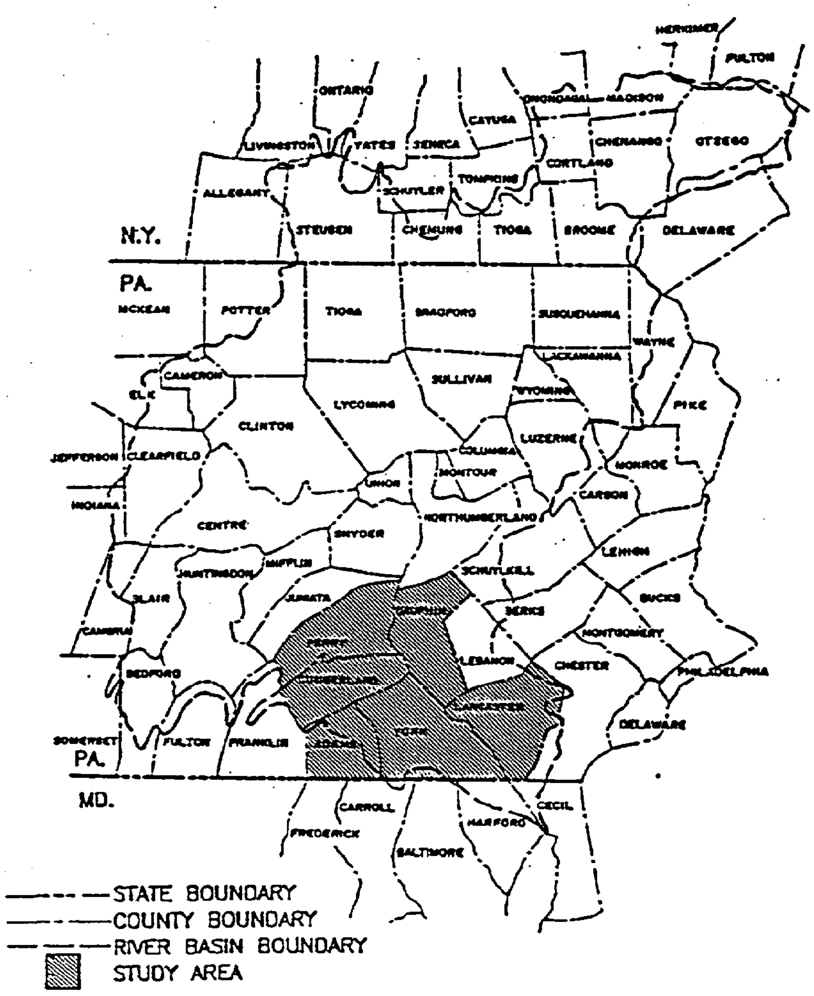

FIGURE 3. LOCATION OF STUDY AREA (COUNTIES)

This area contains all of the York and Lancaster Metropolitan Statistical Areas (MSA's) and approximately three-quarters of the Harrisburg-Carlisle-Lebanon MSA.

Limitations of Land Use Data

Ideally, land use data having the following characteristics would have been used in the analysis:

1. The total land area is divided into major land use categories such as:

Urban Land	Wooded Land
Cropland	Other Land
Pasture	

2. Land use data are available for all geographic areas of interest for at least three fairly evenly spaced points in time during the period 1970 to 1985.
3. The definitions of land uses are consistent from one time period to the next.
4. Land use data are available by hydrologic area, e.g., the Conestoga River watershed.

Not unexpectedly no single data series was found that met all of the criteria. An available data set having the desired land use categories was limited to three of the six counties of interest. The only other data set with explicit land use categories had both time frame and consistency of definition problems. At that point, it was concluded that a meaningful analysis based on land use grouping per se was not possible. Data from the censuses of population and agriculture were used instead.

Previous Investigations

Past water quality assessments from other investigators provide useful insights on problems or problem areas affecting surface water quality. Past assessments of the Lower Susquehanna River Basin by Takita (1977) and PA Bureau of Water Quality Management (1975, 1977, 1980, 1982, and 1986) indicate areas of point and nonpoint sources of pollution.

Takita's (1977) investigation showed that in the Conodoguinet Creek and the Yellow Breeches Creek phosphorus, ammonia, and nitrate-nitrogen came primarily from point sources while in West Conewago Creek, South Branch Codorus Creek, and Conestoga River the same nutrients generally came from nonpoint sources. Takita (1977) also concluded that the West Conewago Creek and Conestoga River were the greatest contributors of nitrate-nitrogen of the fourteen watersheds investigated. Although the West Conewago Creek had the greatest loadings of ammonia and phosphorus, the highest concentrations of nutrients were recorded in the Conestoga River.

Several water quality assessments have been completed by the PA DER, Bureau of Water Quality Management. The latest, "Commonwealth of Pennsylvania, 1986 Water Quality Assessment", indicates that agricultural and mining activities were the major causes of stream degradation in the lower Susquehanna River region. Stream degradation due to mining activities was limited primarily to the head waters of the Swatara Creek watershed. Intense agricultural activity including excessive application of fertilizers and manure management problems due to density of livestock appeared to be the main source of nutrient enrichment of surface water. The Conestoga River, Mill Creek, and South Branch Codorus Creek were identified as some of the streams most affected by agricultural activities.

Stream segments in certain watersheds also receive nutrients from point sources. The lower reach of Codorus Creek, South Branch Codorus Creek, lower reach Conestoga Creek, Conodoguinet Creek from Letterkenny Reservoir to the mouth, Swatara Creek from Lorberry Creek to the mouth, Little Conewago, and South Branch West Conewago all receive the discharges from waste treatment plants. Moreover, these areas are all growing at rates at or above the Pennsylvania state average.

HISTORICAL LAND USE CHANGES

Population

The study area is increasing in population at a rate that far exceeds that of the state as a whole. In the decade 1970-80, the state's population increased by only one-half of one percent. By contrast, the population increases in the six counties of the study area ranged from 3.9 percent to 24.8 percent, averaging 12.3 percent. Population trends for each county are shown in Figure 4.

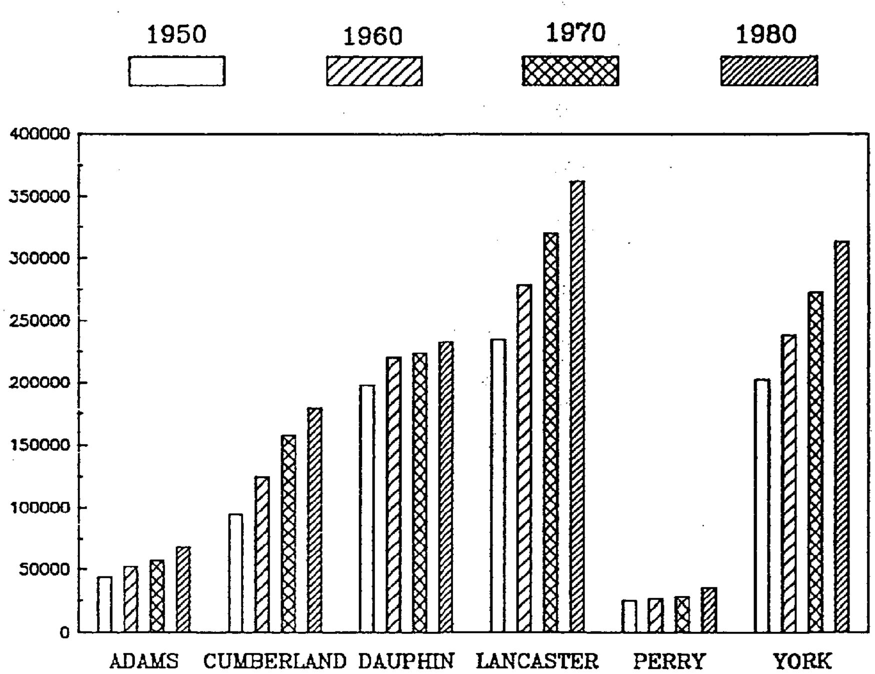

Figure 4. Population Trends

Urban-Rural Trends

Pennsylvania has the largest rural population--farm and nonfarm--of any state in the nation. More than 3.6 million of its inhabitants were so classified in the 1980 census.

Since 1950, the U.S. Bureau of the Census (1971) has defined "urban population" in the following manner:

> "[T]he urban population consists of all persons living in (a) places of 2,500 inhabitants or more incorporated as cities, villages, boroughs, and towns...(b) unincorporated places of 2,500 inhabitants or more...The population not classified as urban constitutes the rural population."

An urban-rural breakdown of the county and state population for the last four censuses is given in Table 3. Since the counties of interest are all part of metropolitan statistical areas, it seems likely that major population growth would have occurred in the urban areas. Table 3 shows a more complex pattern. While exceptions are apparent among the individual counties, the six county totals are consistent with the following observations:

a. The fifties were the time of the "baby boom" generation, with large population increases nearly everywhere;

b. The sixties saw the major moves to nearby, i.e., "urban", townships, causing urban growth to greatly exceed that in rural townships;

c. The seventies were the decade of migration to the more distant smaller and rural townships, occasioned by improved transportation and the lack of space in nearby

TABLE 3.

URBAN AND RURAL POPULATIONS FOR SELECTED COUNTIES: 1950-80

COUNTY/STATE	POPULATION				PERCENT CHANGE			POPULATION DENSITY 1980
	1950	1960	1970	1980	50-60	60-70	70-80	(Persons/Sq.Mi.)
ADAMS								
URBAN	12191	13555	13074	12828	11.19	-3.55	-1.88	
RURAL	32006	38351	43863	55464	19.82	14.37	26.45	
TOTAL	44197	51906	56937	68292	17.44	9.69	19.94	131
CUMBERLAND								
URBAN	54854	73727	105202	111201	34.41	42.69	5.70	
RURAL	39603	51089	52975	67340	29.00	3.69	27.12	
TOTAL	94457	124816	158177	178541	32.14	26.73	12.87	326
DAUPHIN								
URBAN	153991	169374	167857	173668	9.99	-0.90	3.46	
RURAL	43793	50881	55977	58649	16.19	10.02	4.77	
TOTAL	197784	220255	223713	232317	11.36	1.57	3.85	440
LANCASTER								
URBAN	115805	137892	173573	197766	19.07	25.88	13.94	
RURAL	118912	140467	146120	164580	18.13	4.02	12.63	
TOTAL	234717	278359	319693	362346	18.59	14.85	13.34	381
PERRY								
URBAN	2158	2580	2328	2452	19.56	-9.77	5.33	
RURAL	22624	24002	26287	33266	6.09	9.52	26.55	
TOTAL	24782	26582	28615	35718	7.26	7.65	24.82	64
YORK								
URBAN	107272	128870	152477	159791	20.13	18.32	4.80	
RURAL	95465	109466	120126	153172	14.67	9.74	27.51	
TOTAL	202737	238336	272603	312963	17.56	14.38	14.81	345
SIX COUNTY TOTALS								
URBAN	446271	525998	614511	657706	17.87	16.83	7.03	
RURAL	352403	414256	445348	532471	17.55	7.51	19.56	
TOTAL	798674	940254	1059738	1190177	17.73	12.71	12.31	297
PENNSYLVANIA								
URBAN	7403036	8102051	8436379	8220851	9.44	4.13	-2.55	
RURAL	3094976	3217315	3357512	3643044	3.95	4.36	8.50	
TOTAL	10498012	11319366	11800766	11863895	7.82	4.25	0.53	264

towns. The central cities continued to lose population as did many of the older boroughs.

The annual average rate of population increase for the study area and the state, given in Table 4, reemphasize the fact that the study area has been growing at roughly three times the rate of the state as a whole.

TABLE 4

COMPOUND AVERAGE ANNUAL RATES OF POPULATION GROWTH FROM 1950 TO 1980

6 Counties	Average Annual Growth Rate (%)
Urban	1.30
Rural	1.39
Total	1.34
Pennsylvania	
Urban	0.35
Rural	0.54
Total	0.51

Land In Farms

The primary data source for this and the following discussion of agriculture is the U.S. Censuses of Agriculture for the various years. As noted in the introduction to the 1982 Census, "In general, data for 1982, 1978, and 1974 are not fully comparable with data for 1969...due to changes in the farm definition. Data on acreages and inventories for 1982 and 1978 are generally comparable" (U.S. Bureau of the Census, 1983). Any incomparabilities that exist, however, probably do not seriously distort the trends shown in the analyses that follow. Moreover, the data for all of the counties are subject to the same incomparabilities.

With the constant upward trend of population in all counties (Figure 4), an accompanying decline of land devoted to agriculture might be expected. Once again the process of converting land from agriculture to other uses is more complex than the simple relationship suggested above.

Several studies have shown that the relationships between population increases, urbanization and loss of cropland are complex and dynamic. For example, one study (Zeimetz and others, 1976) examined land use changes in 53 counties that had experienced rapid population growth during the period 1961-1970. Of the land converted to urban uses, 35 percent had been cropland, 33 percent open idle land, 28 percent forest, and 4 percent pasture. Concurrently, there had been shifts in both directions among these same four land use categories. That is, substantial amounts of land were converted from cropland to the open idle category, and, to a lesser extent, from open idle to cropland. Similar conversions occurred between cropland and forest, cropland and pasture, pasture and forest, open idle and forest, and pasture and open idle.

Some studies have computed a cropland urbanized coefficient, i.e. acres of cropland lost per population increase. The Zeimetz study (1976) found that such coefficients varied among different regions of the country and declined over time within a given area.

It is clear, then, that the conversion of land out of agriculture is a complex phenomenon, with urbanization being only one factor influencing land use. Other factors that have been cited include changes in farm enterprises, technology and government programs (Hart, 1968). With this as a national perspective, the following sets of data relate to agriculture in the study area. The total acreage in farms in the study counties is displayed in Figure 5. The percentages of the counties total

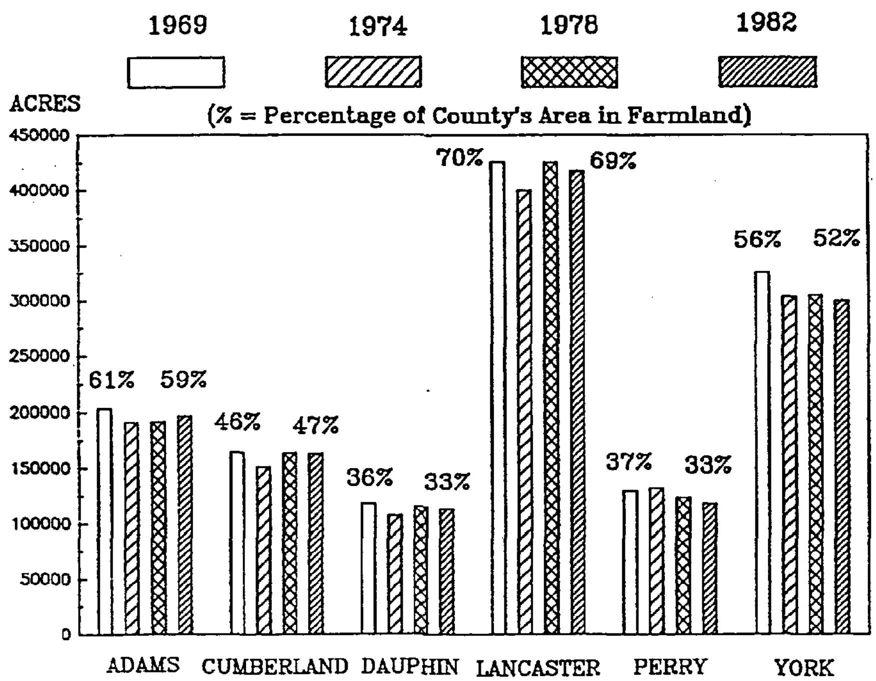

Figure 5. Total Farmland Area

area devoted to farms is also indicated. The relatively modest changes in farmland mirror the national trends in agriculture. The latter part of the sixties were a time of a robust agriculture, characterized by "fence row to fence row" planting. By the early seventies commodity prices were down and marginal operations went out of business. The later part of the seventies were the time of major export sales and a revitalized farm economy bringing land back into production. Finally, the eighties once again saw declining commodity prices and major Federal supply control programs. The result was a movement of land out of production (Personal communication, staff, Land Use Branch, Economic Research Service USDA, 1987).

Livestock and Poultry Inventories

A potential and often existing major source of surface and groundwater contamination is the manure produced by the farm animal population. In this section, the animal populations are tabulated by species and the numbers converted to a common basis--the "animal unit". In this way the various populations can be added up in a meaningful way. The next sections estimate the quantity of manure and nutrients produced by the animal populations.

An "animal unit" is defined as 1,000 pounds, live weight, of the species in question. Thus, if a cow weighs 1,000 pounds, one cow equals one animal unit; if hogs average 200 pounds each, five hogs equal one animal unit; if a laying hen weighs four pounds, 250 hens equals one animal unit, etc.

For ease of analysis, certain simplifying assumptions were made about the average size of the various species and the average population where the farm populations turn over frequently, e.g., broilers. Should the simplifying assumptions bias the estimates in one direction or the other, the conclusions will not be affected since we are making side-by-side comparisons or observing time trends. A constant bias does not distort these relationships. The situation would be quite different if the numerical value of a particular point estimate were of interest.

In general, the Agricultural Censuses are reports of end of the year inventories and total sales during the year. In some instances, age subcategories of the various types of livestock and poultry are included in the inventory data. For the tabulations reported below, the end of the year inventories of the various species were taken to represent the average year-round population. The reasonableness of this assumption was tested by comparing the inventories to the reported annual sales. It was found, for example, that for hogs, which farrow twice a year, sales were approximately double the inventory. Similarly, broiler sales were five to six times the inventory.

The following average weights were assumed for making the population to animal unit conversion. The weights to some degree are assumed to account for the heavier breeding stock and the lighter young growing stock included in the inventories.

Animal Type	Average Weight	Number of Animals Per Animal Unit
Dairy Cow	1,000 lbs.	1
Beef Cow	1,000 lbs.	1
Hog	200 lbs.	5
Poultry-Laying Hen	4 lbs.	250
Broiler	2 lbs.	500

The number of animal units of the various species are shown in Figures 6 through 9. As was the case with farm land, the number of animal units in Lancaster County dominate all of the other counties in the study area. Moreover, the number of animal units is increasing over time for all species of animals in Lancaster County, whereas in the other areas the numbers, with minor exceptions, remain relatively unchanged.

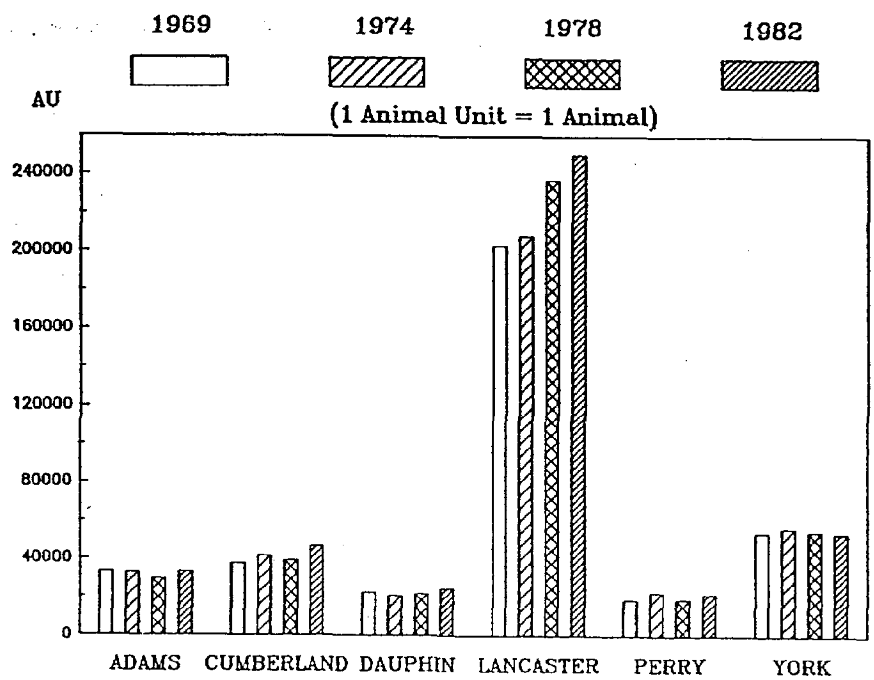

Figure 6. Cattle & Calves--End of Year Inventory

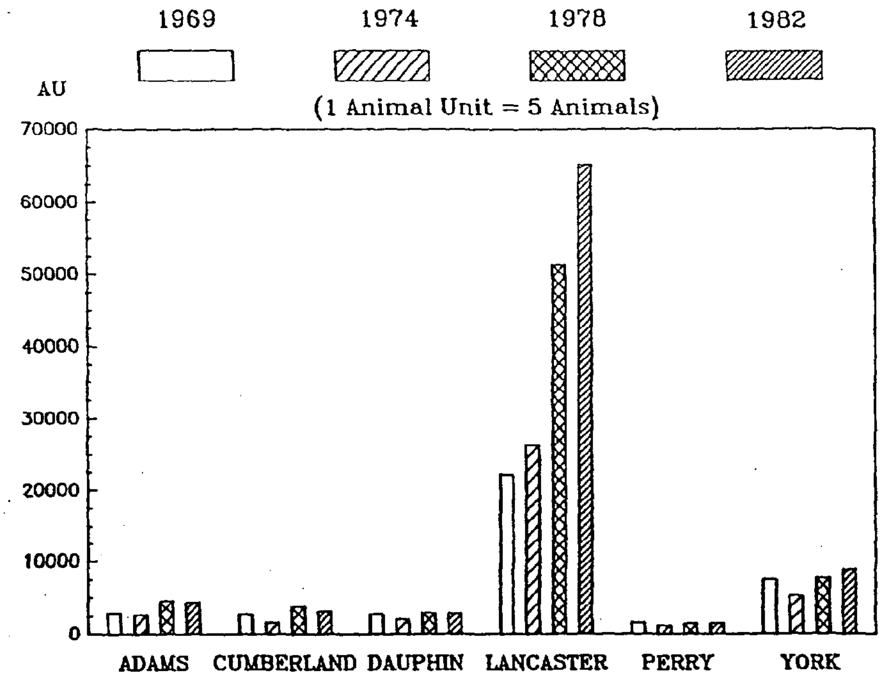

Figure 7. Hogs & Pigs--End of Year Inventory

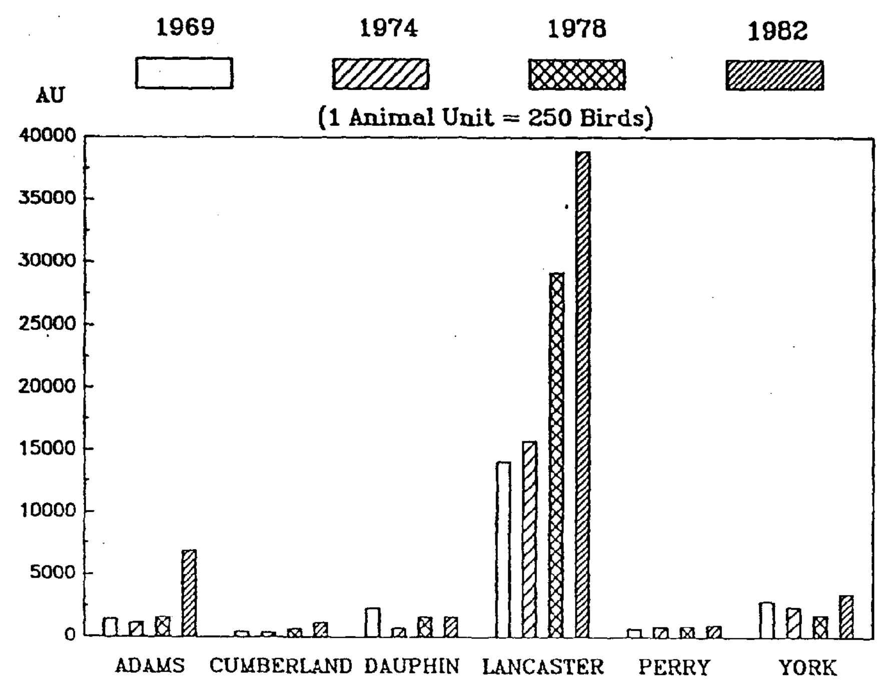

Figure 8. Laying Age Hens--End of Year Inventory

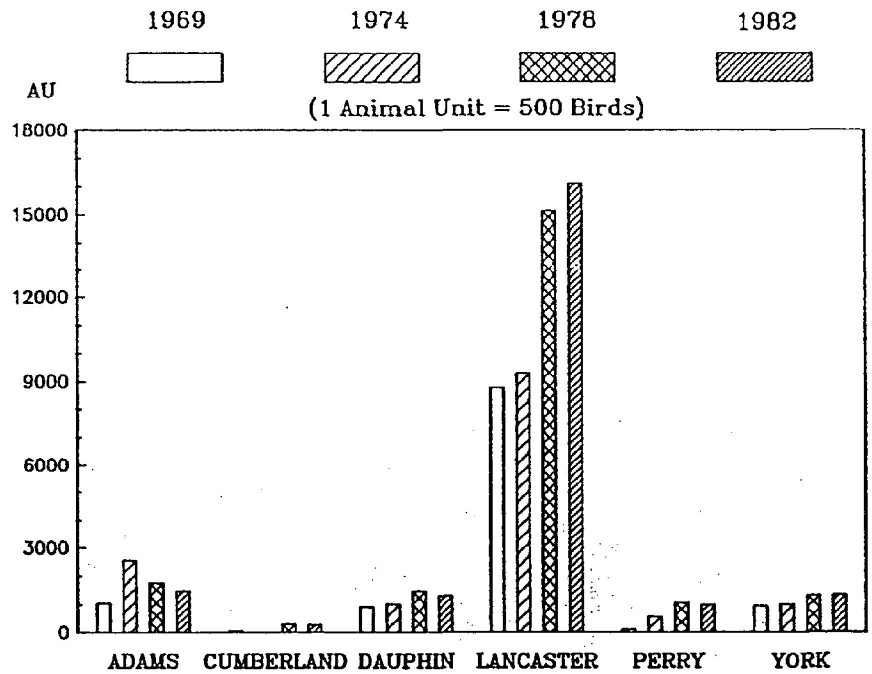

Figure 9. Broilers--End of Year Inventory

Animal Waste Production

From the animal population estimates, it is possible to estimate the quantity of manure produced annually, using the information given in Table 5. The manure production coefficients (tons/AU/year) for each species were applied to the animal unit estimates to compute the animal waste produced by each species. These quantities were then summed to estimate the tons of manure from all animal types. This information is shown in Figure 10.

TABLE 5

MANURE PRODUCTION AND NUTRIENT CONTENT AS PRODUCED

Animal Type	Avg. Size (lbs.)	Total Manure Produced Daily (lbs/AU)*	Total Manure Produced Annual (Tons/AU)*	Nutrient Content (lbs/ton Manure) N*	P*	K*
Cattle						
Dairy	1,000	82	15	10	2	7
Beef	1,000	60	11	11	4	8
Hogs	200	65	12	14	5	9
Poultry						
Layers	4	53	10	28	11	11
Broilers	2	70	13	34	8	11

*AU= Animal Unit= 1,000 pounds live weight; N= Total Nitrogen; P= Elemental Phosphorus; K= Elemental Potassium; P_2O_5= 2.27 x P; K_2O= 1.20 x K.

Source: Midwest Plan Service, 1985.

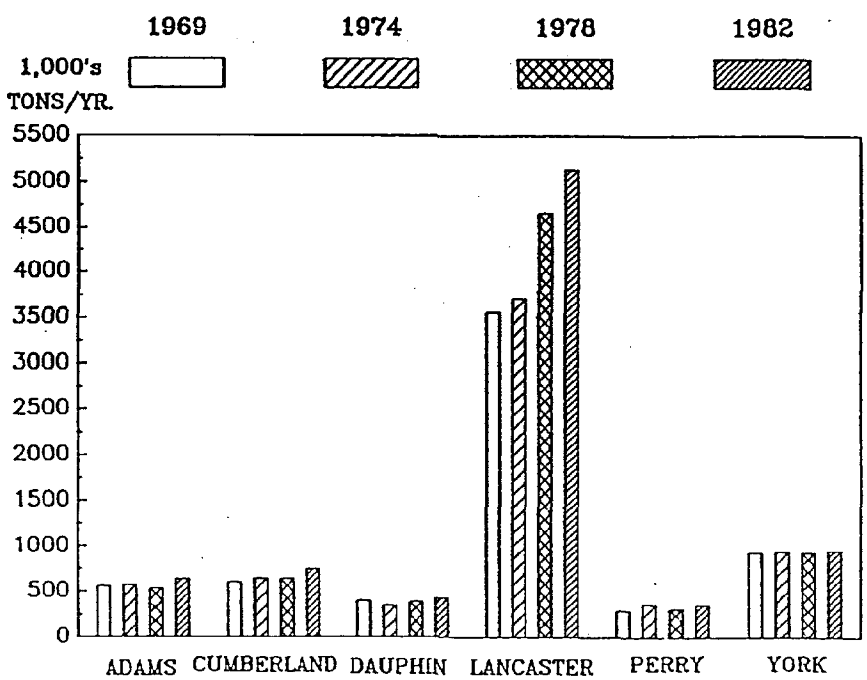

Figure 10. Total Manure Produced By All Species

From an environmental management perspective, the amount of animal waste produced per unit area, or what may be termed the "manure concentration ratio" is of particular interest, If animal populations increase while farmland declines, the use of the land is intensified. To search for such a trend, the total quantity of manure produced was divided by the total land area devoted to crops and pasture for each time period in each county. The resulting ratios, having the units "tons of manure per acre per year" are graphed in Figure 11. As shown there, with the exception of Lancaster County, the ratios have been small (less than 6 tons per acre) and essentially unchanged over time. The ratios for Lancaster County reflect the growing numbers of all animal types (Figures 6-9) and a flat or slightly downward trending farmland base (Figure 5). The result is sharply escalating ratios, demonstrating an intensification or concentration of animal wastes produced per unit of land area.

Estimates of the nutrient content--nitrogen, phosphorus or potassium--can be made using the nutrient content coefficients (pounds of nutrient per ton of manure) given in Table 5. If nutrient ratios (pounds per acre per year) are computed, their plots are very similar in appearance to Figure 11, but with different units on the vertical axes. For instance, in the case of nitrogen, the ratio hovers around 50 pounds per acre for all time periods in all of the counties but Lancaster. In Lancaster, the value of the ratio was about 115 in 1969 and increased to about 180 in 1982.

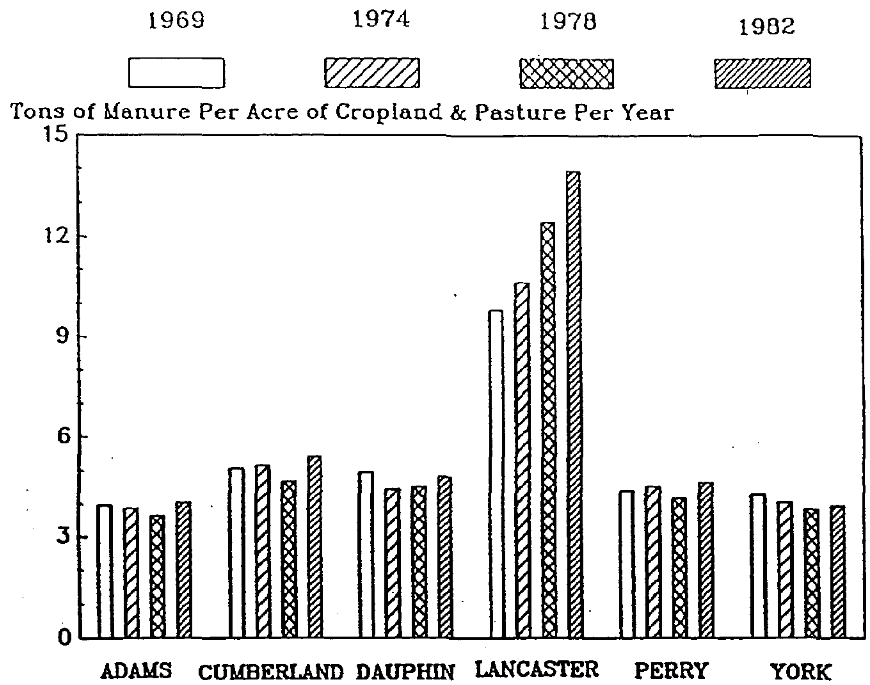

Figure 11. Manure Concentration Ratio

Topography and Ground Cover

Regardless of the lack of specific land use information, it is possible to make inferences about the development path of an area from information about its topography and predominant ground cover. Table 6 gives two data items for each county in the study area: (1) the proportion of each that is forested; and, (2) the ratio of lands having few restrictions on their use as cropland to lands that are unsuited for cultivation. These data are 1982 spot estimates made by the U.S. Department of Agriculture's Soil Conservation Service and utilize the soil capability classification system of SCS.

TABLE 6

PROPORTION OF LAND AREA THAT IS FORESTED, AND CROPLAND SUITABILITY RATIO

County	Percentage Forested	Ratio: Land Suitable for Cropping / Land Unsuitable for Cropping
Adams	27	2.9
Cumberland	35	1.5
Dauphin	43	1.0
Lancaster	12	5.9
Perry	67	0.5
York	26	2.2

Correlation coefficient, r, for two variables: -0.85

(Source: Soil Conservation Service, 1985)

Because wooded areas tend to occur on steep slopes, Perry County can correctly be inferred to be quite mountainous, and the least densely populated county (64 persons/sq. mile). At the other extreme, Lancaster County is one of the top dozen agricultural counties in the nation in terms of the total value of agricultural products sold. With only about 12 percent of its area wooded, Lancaster has almost 6 acres of Class I through Class III land for every acre of Classes V through VIII land. By contrast, the ratio is 0.5 acres to 1 acre in Perry County. As indicated in the table above, the remaining counties fall in intermediate positions in terms of both wooded cover and the ratio of "high quality" to "low quality" lands (relative to agricultural production).

Total Cash Receipts by Farmers

One final measure of the magnitude of the agricultural sector in the several counties is the amount of revenue generated by farm sales. Such estimates, with a breakdown between crop and livestock sales, are shown in Table 7. As was the case in the preceding table, the data presented here are for a single year, 1984. The primary purpose of these data is to show the relative size of agricultural activities in the counties. A single data set from a particular year is sufficient to do that. While a time series of the estimates could be developed, a price deflator would be needed to convert the estimates from a "current dollar" to a "constant dollar" basis. It is felt that time trends are better measured by physical counts of acreages and animal populations.

The table clearly illustrates the substantial role the livestock industry plays in the area's agricultural economy.

TABLE 7

CASH RECEIPTS FROM SALE OF AGRICULTURAL PRODUCTS, BY COUNTY IN 1984

County	Sales in thousand dollars: From All Crops	From Livestock & Livestock Products	Total Cash Receipts By Farmers
Adams	42,410	61,667	104,077
Cumberland	12,682	66,483	79,165
Dauphin	8,431	36,845	45,276
Lancaster	48,529	527,872	576,401
Perry	4,943	30,032	34,975
York	35,990	71,949	107,939
	152,985	794,848	947,833

Source: PA Agricultural Statistics Service, 1985, p. 55-56

WATER QUALITY TRENDS AND LAND USE

Cumberland County & Conodoguinet Creek and Yellow Breeches Creek Watersheds

Cumberland County, part of the Harrisburg-Lebanon-Carlisle Metropolitan Statistical Area, can be divided into three areas. The eastern end of the county is highly developed, containing a substantial residential population. The central and western parts of the county, lying in the center of the Cumberland Valley, is predominantly agricultural. Much of the southern part of the county is mountainous. This latter area is forested and has a low-density, rural non-farm population.

The county has been a high growth area since the fifties (Table 3). Much of this growth was spurred by the opening of two major bridges connecting the City of Harrisburg with the county. One opened in 1953, the other in 1960. The improved access resulted in an increase in the suburban population. More recently growth has slowed in the larger communities, and is occurring primarily in the lower population (<2,500) townships. In fact, several of the older boroughs lost population in the last census (U.S. Bureau of the Census, 1981).

Livestock production dominates the agricultural section in the county. Poultry has shown modest increases in the last two censuses, building from a very small base. Dairy and beef cattle are the major species grown, with milk cows dominating. Their numbers have been increasing steadily since 1970 (PA Agricultural

Statistics Service, 1970, 1975, 1980, 1985). The trend in animal waste production is upward (Figure 10). Moreover, the long term trend in the manure concentration ratio is slightly upward (Figure 11).

Two main tributaries and respective watersheds of the Susquehanna River traverse the agricultural and urban sectors of Cumberland County. These watersheds are the Conodoguinet and Yellow Breeches.

In the northern portion of Cumberland County the Conodoguinet Creek flows northeasterly through moderate to steep slopes of rolling hills and broad valleys. The northern tributaries drain mixed forested and agricultural areas underlain by shale bedrock. Agricultural activities in areas underlain by carbonate rocks are the primary land uses in the remaining parts of the watershed. Urban concentrations and strip development along Route 11 parallel the lower reach of the Conodoguinet Creek to its confluence with the Susquehanna River.

In 1973, major land uses of the watershed consisted of approximately 45 percent agriculture, 38 percent forest, and 5 percent urban (Takita, 1977). Since the mid-1970's, the lower reach has experienced a dramatic increase in urban growth as agricultural lands are quickly being converted to residential and commercial uses.

Yellow Breeches Creek is located in the southern portion of Cumberland County. The upper reaches drain a forested area underlain by quartzites, schists, rhyolites, and sandstones. The stream flows eastward leaving the steep slopes of South Mountain, the headwater area, down through the rolling hills of the Great Valley Section. Here, the Yellow Breeches Creek flows through mix wooded and agricultural lands underlain by carbonate bedrock until it joins the Susquehanna River.

In 1973, land use consisted of 53 percent forested areas, 39 percent agriculture, and 0.5 percent urban (Takita, 1977) in the watershed. As with most areas in the Harrisburg region, the lower reach area has experienced a steady growth in low- to medium-density residential developments. Areas of high-density residential and commercial uses have developed in the extreme northeast corner of the watershed.

Point sources of nutrients originate from industrial discharges and municipal and non-public sewage treatment plants (STPs). Municipal STPs comprise the major point sources of nutrients in the Conodoguinet and Yellow Breeches watersheds.

Nine municipal wastewater management systems are in the Conodoguinet Creek watershed and yield a combined average design discharge of 19.2 mgd (Table 8). The average discharge of non-public operations is 0.4 million gallons per day (mgd). With the exception of one treatment system, all municipal plants are designed to remove phosphorus in the form of phosphate during the waste treatment operation. Four dischargers operate nitrification processes.

TABLE 8

CONODOGUINET CREEK WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL		OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
Carlisle Boro	8.5	P	N	6/82	NEW
Hampden Twp. WWP	2.5	P	N	12/81	NEW
E. Pennsboro Twp.	2.3	P		2/81	ICT*
Mechanicsburg Boro	2.1	P	N	3/82	ICT*
Hampden Twp. STP	1.8	P		5/78	ICT*
Shippensburg Boro	1.6		N	8/82	ICT*
Carlisle Suburban**	0.4	P			
Newville Boro	0.3	P		5/79	NEW
Newburg-Hopewell	0.1	P		12/85	NEW

* ICT-Increased capacity & treatment
** Non public

Based on the original issue date of NPDES permits, a majority of municipal treatment plants began operations by the mid-1970's. Since that time, three plants have been upgraded to increase the level of treatment and overall capacity to the system, and three new treatment plants were installed.

Four municipal sewage treatment plants are located in the Yellow Breeches watershed and have a combined average design discharge of 1.59 mgd (Table 9). The average discharge of non-public operations is less than 0.5 mgd. All municipal STPs are designed to remove phosphorus during the waste treatment operation while three STPs have nitrification processes.

TABLE 9

YELLOW BREECHES CREEK WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL		OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
Mt. Holly Springs	0.338	P	N	8/83	ICT*
S. Middleton Twp.	0.750	P	N	6/77	NEW
Upper Allen Twp.	0.200	P		6/80	NEW
Dillsburg Boro	0.300	P	N	12/83	INC**

* ICT- Increased capacity & treatment
**INC- Increased capacity

Based on the issue date of NPDES permits, the four municipal plants began operating during the 1970-1986 study period. Since that time, selected treatment plants have been upgraded to increase the level of treatment and/or increase the overall capacity of the system.

A review of SIC codes for industrial waste discharges in the watershed indicated that only one industry, Holly Milk Cooperative (SIC 2023), is a nutrient generator. Holly Milk discharges an average of 96,000 gallons per day to Mountain Creek, a tributary of the Yellow Breeches Creek. The estimated concentrations of nutrients for this type of economic activity are about 10.8 mg/l and 61.2 mg/l for total phosphorus and total kjeldahl nitrogen, respectively, according to the Chesapeake Bay Program (1982).

Analysis of Water Quality Data

Conodoguinet Creek Watershed

Data from two water quality stations on the Conodoguinet Creek were examined for trends in nutrient concentrations and loads. Station WQN0213 is located upstream of most urban areas with the exception of Carlisle. This site represents 432 square miles of a watershed consisting primarily of agricultural and forested land uses. Station WQN0240 is located near the mouth of the watershed among more urbanized areas and represents 504 square miles of the watershed.

The Seasonal Kendall's Tau test was applied to the concentration record for the period 1973-1986 and the transport record for the period 1973-1984. Since the discharge record was inadequate at either of the two sampling sites, mean daily discharge data was prorated from a USGS gaging station (01570000) located between the two sites using the ratio of drainage areas in order to generate a transport record. Trend tests on the time series of flow-adjusted-concentrations were made for those parameters showing significant relationships against discharge. Table 10 summarizes the results of the statistical trend tests. The results of the regression of concentration versus discharge are shown for those cases where the slope of the regression was significant at the 0.1% level.

TABLE 10

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU
FOR STATIONS WQN0213 And WQN0240

WQN0213 (Upstream station)

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	- HS	- HS		*		
Total NH3-N+NH4-N	- S	- HS	0.02	+ S	- S	OTHER
Total NO2-N	- HS	- HS	0.12	- HS	- HS	OTHER
Total NO3-N	+ HS	*		*		
Total NO2-N+NO3-N	+ HS	*		*		
Total INORG-N	+ HS	*		*		

WQN0240 (Downstream station)

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	- HS	- HS		*		
Total NH3-N+NH4-N	- HS	- S	0.16	+ S	*	FLOW
Total NO2-N	- HS	- HS		*		
Total NO3-N	+ HS	*		*		
Total NO2-N+NO3-N	+ HS	*		*		
Total INORG-N	+ HS	*		*		

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
+ - Increasing trend/positive slope.
- - Decreasing trend/negative slope.

Total phosphorus concentrations at both water quality stations averaged 0.17 mg/l (Appendix A.1) during the period of study. Since 1982, the variation in total phosphorus concentrations has decreased considerably when compared to the entire 1973 to 1986 record of monthly concentration values. The time series plot also indicates slightly lower total phosphorus concentrations from 1982 through mid-1986.

The time-series plot of total phosphorus concentrations at station WQN0240 is similar to that of the upstream station (WQN0213). The variation and magnitude of total phosphorus values at station WQN0240 has decreased with concentrations ranging from 0.03 mg/l to 0.22 mg/l. However, beginning in 1985, variations in total phosphorus concentrations seemed to increase gradually.

Statistical analyses of phosphorus concentrations and loads at both stations indicated decreasing trends. Regression analyses of concentration on mean daily discharge did not show any significant relationships. Therefore no tests were performed on the FACs.

During the 1973 to 1986 monthly sampling period, total nitrate-nitrogen at the upstream and downstream sites averaged 3.3 mg/l and 3.5 mg/l, respectively (Appendix A.1).

At station WQN0213, the plot of total nitrite-nitrogen shows a gentle decline in concentration from 1973 to early 1983; no trend is apparent from early 1983 to the end of the record. Total nitrate-nitrogen concentrations remain fairly steady between 1973 through 1983 with concentrations varying from 2 mg/l to 4 mg/l. However, an increase in total nitrate-nitrogen concentrations occurred in 1983; these concentrations vary from 3.5 mg/l to 5.5 mg/l.

As at station WQN0213, the nitrate-nitrogen concentrations increased slightly during 1983 at station WQN0240. However, the increase is smaller than at station WQN0213. The variations in nitrate-nitrogen concentrations with time appear similar at the two stations. Because total nitrate-nitrogen contributes 95 percent of the total inorganic nitrogen, the time series of total inorganic nitrogen closely follows the same pattern as the time series of nitrate-nitrogen.

At station WQN0213, the statistical analysis shows decreasing trends in the concentration and load for nitrite-nitrogen and ammonia-nitrogen, while increasing trends were found in nitrate-nitrogen and total inorganic nitrogen concentration. Regression analyses of these parameters versus discharge resulted in significant relationships for only two parameters: nitrite-nitrogen and ammonia-nitrogen (Table 10). The slopes of the relationships show decreasing concentrations with increasing discharges suggesting that trends in the concentrations may be due to a dilutional effect of flow. However, the test of the FACs indicate that some process change other flow may have caused the slightly decreasing concentrations in total ammonia-nitrogen and total nitrite-nitrogen at station WQN0213.

At station WQN0240, decreasing trends occurred in the concentration and transport records for nitrite-nitrogen and ammonia-nitrogen while the other forms of inorganic nitrogen showed increasing trends. The regression of only one parameter, total ammonia-nitrogen concentration on discharge, resulted in a significant relationship. Results of the FAC procedure indicated that the trend in concentration for this parameter was probably the result of a trend in flows.

The results of the FAC analyses for ammonia-nitrogen indicate that two separate processes are causes of trends in the parameter. There may be more than one process affecting trends in ammonia-nitrogen at the lower station, with flow possibly the dominant process. This may be due to increased surface runoff and discharge from a highly developed area between the two stations.

Yellow Breeches Watershed

One water quality station was examined for trends in nutrient concentrations and loads on the Yellow Breeches Creek. Station WQN0212 is located approximately a half mile upstream from the mouth representing 219 square miles of a predominantly mixed forest and agricultural watershed.

The discharge record for station WQN0212 was incomplete and had to be estimated from records of USGS station 01571500, using the ratio of drainage areas.

During the 1973 to 1986 monthly sampling period, total phosphorus averaged 0.17 mg/l, ranging from 0.03 mg/l to 1.8 mg/l at the water quality station (Appendix A.2). Concentrations of total phosphorus were fairly constant during much of the sampling period and exhibited little response to fluctuations in mean daily discharge.

Statistical tests on the total phosphorus data suggested a declining trend in the transport record (Table 11). However, results from the regression test did not warrant the use of the flow-adjusted-concentration procedure.

TABLE 11

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU FOR STATION WQN0212

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	*	- S		*		
Total NH3-N+NH4-N	- HS	- HS	0.07	+ HS	- HS	OTHER
Total NO2-N	- HS	- HS		*		
Total NO3-N	- S	- S		*		
Total NO2-N+NO3-N	- S	*		*		
Total INORG-N	- HS	- S		*		

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
+ - Increasing trend/positive slope.
- - Decreasing trend/negative slope.

Total inorganic-nitrogen averaged 1.96 mg/l ranging from 0.44 mg/l to 4.32 mg/l, during the sampling period between 1973 to 1986 (Appendix A.2). Total nitrate-nitrogen accounted for 97 percent of the inorganic nitrogen. Average daily load for inorganic nitrogen amounted to 1.6 tons or 14.6 lbs/day per mi^2.

Plots of the nitrogen species concentrations and discharge time series revealed small decreases in total nitrite-nitrogen, total nitrate-nitrogen, and inorganic nitrogen. The small declines in concentration occurred between 1978 and 1979 and remained at the reduced concentrations for the remaining sampling period. Total ammonia-nitrogen concentrations were highly variable and difficult to interpret. However, total ammonia-nitrogen concentrations rarely fell below 0.05 mg/l before 1979 whereas concentrations lower than 0.05 mg/l were common after 1979.

All nitrogen species exhibited trends in concentration and/or load based on the Seasonal Kendall Tau Test. The regression of total ammonia-nitrogen on mean daily discharge resulted in a significant relationship. The trend test on the FACs for total ammonia-nitrogen indicated that some process change other than flow caused reduced concentrations over time.

Assessment

Cumberland County's population will continue to grow at rates well above that of the state, maintaining a mixed rural and urban character. Urbanizing pressures are sufficiently strong that in the long term, agricultural land uses, e.g., beef and dairy operations, will give way to more intensive uses such as residential and business development. Agricultural and urbanizing activities will continue to impact the Conodoguinet watershed more than the Yellow Breeches.

The water quality data of the Yellow Breeches suggest the absence of major degrading influences. This may result from the watershed draining a large percent of forested mountain areas with low intensity agricultural and urban uses in the remaining portion of the watershed.

The evaluation of graphical and statistical tests of the nutrient data do not indicate the occurrence of nutrient enrichment problems. Even though a significant statistical trend was found in the phosphorus transport record, a review of all the analytical procedures did not indicate a definite trend in total phosphorus. The step reduction that occurred in the nitrogen data between 1978 and 1979 is typical of a pattern resulting from a change in a major point source; however, this trend can not be correlated to any changes in past land use activities.

Possible future land use impacts on water quality in the Yellow Breeches may result from the influence of residential development occurring along the lower reaches of the watershed.

The time-series of nutrient data from the two water quality stations on the Conodoguinet Creek indicate a sudden change in the nitrogen and phosphorus concentrations during the time when new municipal sewage treatment plants were installed and existing plants were upgraded.

Beginning around 1982, an increase in nitrate-nitrogen concentrations occurred simultaneously with a decrease in phosphorus, ammonia-nitrogen, and nitrite-nitrogen concentrations. The magnitude of concentration variation in the various parameters was relatively small for the remaining period of record as compared to pre-1982 concentrations. The sudden change in nitrate-nitrogen and phosphorus concentrations corresponds to the period of municipal sewage treatment plant upgrades and establishment of new plants (Table 8) and is consistent with the changes expected to result from such construction. The Carlisle STP discharging into the Conodoguinet Creek probably had the greatest impact on nutrient concentrations. This treatment plant operates both nitrification and phosphorus removal processes discharging at an average design flow of 8.5 mgd.

After the sewage treatment plant installation and upgrade period, total phosphorus concentrations were maintained at lower levels and the variability in those concentrations were reduced. Since early 1985, total phosphorus is showing signs of increasing concentrations and variability, especially at the downstream site. This phenomenon may be attributed to the intense growth in residential development along the lower reach of the watershed. Increased phosphorus concentrations may be expected in the near future as a result of this growth.

Dauphin County & Swatara Creek Watershed

Dauphin County is the most urban county in the study area. While it has the highest population density of any of the study area counties, its population growth has been, with one exception, well below that of the study area as a whole (Table 3). Harrisburg, its central city, as is typical of older cities in the northeast, reached its peak population in 1950, and has been declining ever since (PA Department of Commerce, 1973).

The county has the second to the smallest agricultural sector of the study area counties based on cash receipts (Table 7). It has the least number of acres in farms (Figure 5). The size of the agricultural sector is the result of several factors. As shown in Table 6, over 40 percent of the county is forested and half of the non-urban land is unsuited to cropping, i.e., suitability ratio equals 1.0. Urbanization of the area around Harrisburg also serves to limit the land area available for farming.

Livestock production generates 80 percent of the sales revenues of Dauphin County farmers (Table 7). Animal populations for all species are modest compared with the other counties in the study (Figures 6-9). There is a slight upward trend in both the tons of manure produced annually and the manure concentration ratio (Figures 10 & 11). However, both values are only slightly higher than those for Perry County, the county with the smallest agricultural sector.

Part of the Swatara Creek watershed occupies the central and southern part of Dauphin County. Swatara Creek drains a 576 mi^2 area and flows 71.7 miles southwestward through the mountains and valleys of southcentral Pennsylvania. The headwaters and upper reaches of Swatara Creek originate in the Appalachian Mountain Section, located in Schuylkill County. This area is characterized by narrow valleys having steep mountainous slopes. The middle reach, located in Berks County, crosses the Great Valley with the lower reach, located in Dauphin County, occurring within the Triassic Lowland Section. The middle and lower reaches are contained in a broad valley and rolling hills of moderate slope. The Swatara drains much of the lower half of Dauphin County, including the larger population, suburbanized townships of Derry, Lower Paxton and Swatara. The remainder of the drainage is comprised of small (<7,000 persons) urban townships and rural areas. Based on the relatively modest population growth and farm activity in the county, the Swatara is expected to have water quality comparable to the Conodoguinet.

The Swatara Creek watershed consisted of approximately 52 percent agricultural lands, 37.1 percent forest lands, and 1.2 percent urban lands in 1973 (Takita, 1977). It is important to note that 7.0 percent of the watershed's land is considered disturbed, referring to strip mines located in the northern part of the basin. Most urbanized areas are located east of Harrisburg along Route 422 towards the city of Lebanon and the surrounding area where agricultural lands are being converted to other urban developments and highway expansion.

Thirteen municipal wastewater management systems are located in the Swatara Creek watershed and yield a total average design discharge of more than 15 mgd (Table 12). Most systems are located in the southern portion of the watershed around Route 422. With the exception of Lebanon City, the municipal STPs discharge relatively small amounts of treated wastewater. Some form of phosphorus removal takes place at nearly all the facilities, while only two facilities operate nitrification processes by the attached or suspended growth methods.

TABLE 12

SWATARA CREEK WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL	OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
Lebanon City/STP	6.3	P N	10/74	NEW
Swatara Twp. Auth.	3.0	P	7/74	NEW
Derry Twp. M. A.	2.75	P	8/74	NEW
Palmyra Boro Auth.	1.42	P	7/83	ICT*
Annville Twp. Auth.	0.75		6/81	ICT*
North Lebanon Co. A.	0.40	P	5/82	NEW
S. Londonderry/West	0.173	P	Before 3/74	NEW
Fredericksburg S & W	0.15	P	7/84	NEW
S. Londonderry/East	0.06	P N	6/81	NEW
Frailey Twp. Sewer	?	?	?	?
Pine Grove Boro S.	?	?	?	?
Pine Grove Twp. S. A.	multiple discharge points		?	?
Tremont Munc. S. A.	?	?	?	?

*ICT-Increased capacity & treatment

In the Swatara Creek watershed, firms associated with the manufacturing of food and kindred products (SIC 20) are the major economic activities with the greatest potential to generate nutrients. As indicated in Table 13, poultry processing (SIC 2016) and animal oil manufacturing (SIC 2077) produce high nutrient concentrations. The largest and major employer in the food and kindred products industry is the Hershey Chocolate Company (SIC 2066). However, most discharges from this firm are cooling waters utilized in plant operations.

TABLE 13

SWATARA CREEK WATERSHED
FIRMS CONSIDERED NUTRIENT GENERATORS

FACILITY NAME	SIC CODE
Grimes Poultry	2016
College Hill Poultry	2016
Keystone Protein Co.	2077
Manbeck Poultry	2016

Analysis of Water Quality Data

Swatara Creek Watershed

One water quality station, WQN0211, was selected for trend analyses in nutrient concentrations and loads on the Swatara Creek. It is located at the Route 441 bridge in Middletown and represents 571 mi^2 or 99 percent of the watershed area.

Graphic and statistical procedures were performed on the monthly concentration (1973-1986) and transport (1975-1985) data. Transport records were constructed utilizing mean daily discharge data from USGS gaging station 01573560 and prorating the discharge data to the water quality network station using the ratio of drainage areas. Trend tests were made on the flow-adjusted-concentrations for total phosphorus and total nitrite-nitrogen.

Total phosphorus averaged 0.25 mg/l during the 1973-1986 monthly sampling period and averaged 2.1 lbs/day per mi^2 from 1975 to 1985 (Appendix A.3). A visual inspection of the time series plot of the transport record did not reveal any apparent trends. However, a slight trend was apparent in the concentration record. Between 1973 and 1981, most phosphorus concentrations varied from 0.04 mg/l to 0.4 mg/l. This large variation exhibited little response to fluctuations in mean daily discharge. Monthly samples of total phosphorus concentrations after 1981 were fairly constant with only 16 percent of the values exceeding 0.2 mg/l.

Testing the phosphorus data with the Seasonal Kendall's Tau procedure indicated a declining trend in the transport time series but no trend in the concentration record (Table 14). The relationship between streamflow and total phosphorus concentration was weak but significant. Analysis of the FACs suggested a decline in total phosphorus has occurred due to some process change other than that related to flow.

TABLE 14

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU
FOR STATION WQN0211

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	*	- S	0.04	- S	- HS	OTHER
Total NH3-N+NH4-N	*	*				
Total NO2-N	- HS	- HS	0.11	- HS	- HS	OTHER
Total NO3-N	+ HS	*		*		
Total NO2-N+NO3-N	+ HS	*		*		
Total INORG-N	+ HS	*		*		

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends
in discharge
Other-Trends in concentration of load result from processes
other than discharge
\+ - Increasing trend/positive slope.
\- - Decreasing trend/negative slope.

Total inorganic nitrogen averaged 3.7 mg/l. The time series plot of inorganic nitrogen showed an increasing trend in the concentration record but revealed no trend in the transport record. Nitrate-nitrogen was the most abundant form of inorganic nitrogen, accounting for 95 percent of total inorganic nitrogen. The time series plot of total nitrate-nitrogen revealed a slightly increasing trend in concentration. Nitrate-nitrogen showed little response to fluctuations in streamflow. The time series plot of total ammonia-nitrogen concentration failed to exhibit any apparent trend. Concentrations of total nitrite-nitrogen were highly variable during the period of record; however, lower nitrite-nitrogen concentrations were more prevalent after 1979. The statistical analysis of nitrite-nitrogen indicated decreasing trends in concentration and loads and was the only parameter that showed a relationship to streamflow. Results of the trend test on the FACs for nitrite-nitrogen suggests that some process change has taken place, resulting in reduced inputs of nitrite-nitrogen to Swatara Creek.

Assessment

Dauphin will remain an urban county, but with population growth well below that of the six county study area. In the agricultural sector the increase in manure generation between 1978 and 1982 was associated entirely with an increase in the number of cattle and calves on farms, the number of animal units of all other species having declined during that period.

Results of the trend testing procedures show a declining trend in FACs of total phosphorus suggesting that the declining trend in phosphorus load (Table 14) is due to processes other than discharge. During the study period, the implementation of phosphorus reduction and removal techniques at municipal wastewater treatment plants may have aided in the reduction of phosphorus delivered to surface waters.

Nitrogen concentration exhibited increasing trends in nitrate-nitrogen and total inorganic nitrogen in the Swatara Creek. These increasing trends support other studies (PA DER, 1975, 1977, 1980, 1982, 1986; Fishel and Richardson, 1985) where higher nitrate-nitrogen concentrations existed in streams draining agricultural areas. The reduced inputs of nitrite-nitrogen can not be attributed to any relationships in changing land use activities. A declining trend in nitrite-nitrogen may be an artifact of chemical, physical, and biological processes acting upon this unstable form of inorganic nitrogen.

Lancaster County & Conestoga River Watershed

Lancaster County has the largest land area, the largest population, and the largest agricultural sector in the study area as is clearly shown in Figures 4 through 11.

Lancaster County is a metropolitan statistical area (MSA), ranking 88th among the nation's 281 MSA's in 1985 (The Patriot, July 30, 1986, p. A-12). At the same time nationally it was the 11th ranking county in value of all agricultural products sold in 1982 (PA Agricultural Statistics Service, 1985, p. 61). It and 14th ranked Palm Beach County, Florida were the only counties east of the Mississippi River in the top ranking 25 agricultural counties.

About 2,000 to 3,000 acres of land are estimated to be moving out of agriculture each year (Personal communication, Director of the Lancaster County Planning Commission, 1987). The long term (1950-80) population increase has averaged about 4,300 persons per year (Table 3).

Lancaster County leads the Commonwealth in the production of corn, hay and tobacco, and ranks second among all counties in producing barley and peaches (PA Agricultural Statistics Service, 1985, p. 59). However, the livestock sector dominates the county's agriculture. In 1984, 92 percent of farm income came from the sale of livestock and livestock products, eggs and milk (Table 7). Even more significant is the rate at which the farm animal populations have grown between the 1969 and 1982 censuses. For instance in 1969 the county produced 19.7 million broilers and other meat type birds. By 1982 this number had reached 46.6 million. Similar growth increases for cattle, hogs and laying hens are shown in Figures 6-8. Simultaneously, there has been a growth in the quantity of animal manures requiring disposal. Of greater concern than the increased quantities of wastes is the sharply increasing manure concentration ratio. With the amount of land in farming static or even declining slightly, the growing production of manure leads to higher and higher amounts of animal wastes to be disposed of per unit of cultivated land. Figure 10 shows the magnitude of the problem. The ratios for all of the other counties have hovered around 4 to 5 tons per acre. The ratio for Lancaster in 1969 was 10 tons per acre and reached 14 tons per acre in 1982. Not surprisingly degradation of Conestoga River by runoff from agricultural lands is occurring.

The Conestoga River drains a 477 mi^2 area in the Piedmont Province and flows west for 20 miles before changing to a southwest course for 40 miles. The topography surrounding the upper and middle reaches of the Conestoga River is characterized by rolling hills with mild slopes in a broad valley. A narrowing valley with hills of moderate slopes defines the terrain along the lower reach of the main channel.

Major land uses in the watershed consisted of 59 percent agriculture, 31 percent forest, and 1 percent urban in 1973 (Takita, 1977). The forested lands are located primarily along the northern boundary of the drainage area. Urbanized areas include the City of Lancaster, and the Boroughs of Ephrata, Lititz, Ephrata, New Holland, and Millersville. Growth and suburbanization continues in the area surrounding Lancaster.

A total of twelve municipal wastewater management systems are located in the Conestoga River watershed, with a combined average design discharge of 45.3 mgd (Table 15). The three STPs in the Lancaster City area contribute 83 percent of the total municipal waste discharge. According to a treatment plant and discharge point report obtained from the DER Bureau of Water Quality Management (Bonnie Morrow, personal communication), most sewage treatment plants in the watershed lack significant phosphorous removal and nitrification processes.

TABLE 15

CONESTOGA RIVER WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL		OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
Lancaster Area S A	23.0			6/77	NEW
N. Lancaster City	12.0			10/74	NEW
S. Lancaster City	2.9			10/74	NEW
Lititz S A	2.4	P	N	7/82	ICT*
Ephrata Boro	1.9			10/74	NEW
New Holland Boro	1.2			7/89	ICT*
Millersville Boro	1.0			7/74	NEW
North Lancaster Co	0.35		N	12/81	NEW
Adamstown S A	0.30			5/74	NEW
Terre Hill Boro	0.21			5/74	NEW
Caernarvon Twp.	?	?		?	?
Elverton Boro	?	?		?	?

*ICT-Increased capacity & treatment

A review of NPDES permitted industrial waste dischargers and their associated SIC codes revealed that 3 of 20 industrial dischargers are considered nutrient generators (Table 16). Two are associated with agricultural products: (SIC 2016-poultry processing and SIC 2035-pickled fruits and vegetables).

TABLE 16

CONESTOGA RIVER WATERSHED
FIRMS CONSIDERED NUTRIENT GENERATORS

FACILITY NAME	SIC CODE
Air Products & Chemicals	2813
Victor F. Weaver, Inc.	2016
Spring Glen Farms, Inc.	2035

Analysis of Water Quality Data

Conestoga River Watershed

Data for two water quality stations were examined for nutrient trends in concentrations and loads on the Conestoga River. The upstream station, WQN0205, is located northeast of Lancaster where Route 230 crosses the River. This station represents 324 mi^2 of a watershed containing intense agricultural activity. Station WQN0231 is located downstream of Lancaster City and its growing suburban areas. It represents 399 mi^2 of the watershed.

Graphical and statistical procedures were performed on the concentration records (1973-1986) and the transport records (1973-1984) at both stations and evaluated for trends. Transport records were constructed for both stations utilizing mean daily discharge data from a USGS gaging station (01576500) to calculate mean daily load for each monthly sample.

During the period of study, average total phosphorus concentrations varied quite differently between the two water quality stations. At the upstream station, total phosphorus averaged 0.28 mg/l or 1.8 lbs/day per mi^2 while the downstream station averaged 0.59 mg/l or 3.6 lbs/day per mi^2 (Appendix A.4).

A visual comparison of the total phosphorus time series plots to that of mean daily discharge indicates that elevated concentrations generally occurred during times of lower mean daily flows at both stations. This effect is more pronounced at the downstream water quality station. Between 1980 and 1982, observed phosphorus concentrations were notably higher, coinciding with a sequence of lower mean daily flows. Other than this three year period, total phosphorus exhibited large variations in concentration making interpretation of any trends difficult.

Statistical analyses of the data showed declining trends in concentrations and loads of phosphorous at both water quality stations on the Conestoga River (Table 17). At the downstream station, WQN0231, the analyses indicate the existence of a significant trend in concentration and a highly significant trend in load. Such findings may indicate that the trend in concentration is a consequence of a particular sequence of discharges. The regression of concentration vs. discharge was weak but significant. Trend test applied to the FACs suggest that some process change may have reduced inputs of phosphorus to the Conestoga River but flow conditions masked the effect of this change. An analysis of the FACs at the upstream site yielded the same conclusions.

Total inorganic nitrogen and total nitrate-nitrogen average concentrations were very similar for both water quality stations. The average concentrations of ammonia-nitrogen and nitrite-nitrogen were approximately twice as high at the downstream station as at the upstream station. Loading of inorganic nitrogen at station WQN0205 and WQN0231 during the period of investigation averaged 45.9 lbs/day per mi^2 and 47.5 lbs/day per mi^2, respectively (Appendix A.4).

TABLE 17

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU FOR STATIONS WQN0205 & WQN0231

WQN0205 (Upstream station)

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	- HS	- HS	0.01	- S	- HS	OTHER
Total NH3-N+NH4-N	- HS	- HS		*		
Total NO2-N	- HS	- HS	0.04	- S	- HS	OTHER
Total NO3-N	+ HS	*		*		
Total NO2-N+NO3-N	+ HS	*		*		
Total INORG-N	+ HS	*		*		

WQN0231 (Downstream station)

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	- S	- HS	0.17	+ HS	- HS	OTHER
Total NH3-N+NH4-N	- S	- S	0.09	+ HS	*	FLOW
Total NO2-N	+ S	*	0.07	+ HS	*	FLOW
Total NO3-N	*	- S	0.03	- S	*	FLOW
Total NO2-N+NO3-N	*	- S	0.02	- S	*	FLOW
Total INORG-N	*	- HS		*		

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
\+ - Increasing trend/positive slope.
\- - Decreasing trend/negative slope.

Time-series plots of concentration and transport were constructed for the various forms of inorganic nitrogen and reviewed for visual trends. The plots revealed similar patterns in the various inorganic nitrogen forms at both sites.

At the downstream station, WQN0231, most ammonia-nitrogen values remained below 1.0 mg/l and exhibited some variability during the period of record. However, ammonia-nitrogen concentrations peaked between 3.0 mg/l and 5.5 mg/l in the early months of 1977, 1981, 1982, 1983. Only the 1981 and 1982 events occurred at the upstream station, WQN0205, with peak concentrations being much lower than the peaks that occurred at the downstream station. With the exception of the 1981 and 1982 events, most ammonia-nitrogen values at the upstream site remained below 0.35 mg/l. No perceptible trends were identified in either time series.

The plots of nitrite-nitrogen at both stations show a tendency towards more variability in concentrations between 1982 to 1986. Nevertheless, a majority of the values during this period were much lower than the values that occurred prior to 1982. Slightly declining trends in nitrite-nitrogen concentrations are discernible in the time series data for both stations.

Total nitrate-nitrogen concentrations were highly variable at both sites during the period of investigation but increasing trends were still visible on the plots. The increasing trend was much more apparent at the upstream station. Unlike ammonia-nitrogen and nitrite-nitrogen, concentrations of total nitrate-nitrogen were relatively the same at both stations throughout the period of record. Because nitrate-nitrogen comprises the major portion of total inorganic nitrogen, the time series patterns for inorganic nitrogen are similar to those for nitrate-nitrogen.

For the upstream station, the Seasonal Kendall's Tau test results indicated highly significant trends in the concentration and load records for ammonia-nitrogen and nitrite-nitrogen and only for concentration for the other nitrogen species (Table 17). Ammonia-nitrogen and nitrite-nitrogen show declining trends while the other inorganic forms exhibited increasing trends. Only one parameter, nitrite-nitrogen, showed a significant relationship to mean daily discharge. The test of nitrite-nitrogen's FACs indicated a decline in concentration had occurred as a result of a process change other than that of flow.

For the downstream station, WQN0231, declining trends occurred in the transport record for all of the various forms of inorganic nitrogen. The concentration data show a declining trend for ammonia-nitrogen, an increasing trend for nitrite-nitrogen, and no significant trends for the remaining nitrogen species. The analyses of the FAC data did not indicate any trends. This suggests that the trends in concentration and load were indeed artifacts of a particular sequence of discharges and that there is no evidence for any changes in the processes contributing the various forms of inorganic nitrogen to the Conestoga River.

Assessment

The surface waters of the Conestoga watershed have high concentrations of phosphorus and nitrates as well as other pollutants largely because of intensive agricultural activities.

With continued population growth in and around the towns and cities of the watershed, wastewater discharges from municipal STPs have also increased. Even though the wastes are treated, more than 50 percent of Lancaster County's sewage ends up in the Conestoga River (Chesapeake Citizen Report, 1987). The trend in population growth is expected to continue, increasing the amount of wastewater disposal.

Trends in nitrate-nitrogen and total inorganic nitrogen concentrations at the upstream station may be attributed to the land use influences of the agricultural sector. Animal populations, manure production and the manure concentration ratio continues to increase over time. The activity of the agricultural sector contributes to the increasing trends noted in some nutrient concentrations. Much of this increase may be attributed to denser livestock populations in barn yards, feed lots, and pasture areas draining to surface waters.

Declining trends in phosphorus concentrations and load are the opposite of what would be expected based on man's activities in the Conestoga watershed. Even though phosphorus concentrations are relatively high, perhaps increased treatment from municipal STPs has reduced the level of certain pollutants. A second possibility is that the statistical analysis of the data produced false results due to the sampling technique.

Perry County & Sherman Creek Watershed

Perry County has the smallest and most rural population, and the lowest population density (Table 3) in the study area. Its cash receipts from sale of agricultural products were the lowest of the six counties in 1984 (Table 7). Two-thirds of the county is wooded and only one-third is suitable for cropping (Table 6). Thus, the county can be characterized as a rural, mountainous area with small, isolated areas of population and livestock production. As a result of the large proportion of the county in woodland cover, the surface waters are relatively pristine (Appendix A.5).

Sherman Creek flows northeastward through a narrow valley surrounded by mountains, high hills, and ridges within the Appalachian Mountain Section of the Valley and Ridge Province. The stream drains a predominately forested watershed containing agricultural areas along moderate slopes and small valleys. It drops from an altitude of 2,225 feet to 330 feet.

Although a detailed breakdown of land use was not available on a watershed level, land use information was available on a county level and is typical of what is represented in Shermans Creek watershed. In 1974, the Economic Research Service of the

USDA shows Perry County having 62 percent in forest, 28.5 percent in agriculture, and 3.5 percent in urban land uses. Population centers consist of small rural communities scattered throughout the watershed. The largest population center, Duncannon, is situated at the confluence of Sherman Creek and the Susquehanna River. Within the past decade, small rural residential communities have developed in the lower portions of the watershed.

Due to the rural nature of the watershed, only one municipal STP exists in the drainage area. Initiating operations in mid-1981, the Loysville Village STP discharges an average design flow of 0.11 mgd and operates both phosphorus removal and nitrification processes. The remaining STPs are non-public operations contributing a combined discharge of 0.07 mgd from small residential areas and mobile home parks. Original issue dates of NPDES permits indicate that these non-public systems began operations in the early 1980's. The remaining majority of the resident population utilize septic systems.

Analysis of Water Quality Data

Sherman Creek Watershed

One water quality station was examined for trends in nutrient concentrations (1973-1986) and loads (1973-1985) on Sherman Creek. Station WQN0243 is located approximately 2.5 miles upstream of Duncannon and represents 240 square miles of a predominantly forested watershed with small agricultural areas.

The concentration of total phosphorus averaged 0.07 mg/l with an average daily load of 140 lbs or 0.58 lbs/mi^2 (Appendix A.5). The phosphorus data evaluated for the period of study indicates that Sherman Creek has very good water quality. Since the discharge record was incomplete at the water quality station, WQN0243, mean daily discharge data was prorated from a USGS gaging station (01568000) located upstream.

Graphical and statistical analyses of the data did not reveal any trends in total phosphorus concentrations or loads. The data exhibited small variations and concentrations remained fairly constant over the period of record.

During the 1973 to 1986 sampling period, total inorganic nitrogen averaged 1.15 mg/l. Nutrient data monitored at station WQN0243 indicated that water quality in Sherman Creek is very good (Appendix A.5).

Time-series plots of nutrient concentrations and loads did not exhibit any monotonic trends or sudden changes for any parameter except for nitrite-nitrogen. A plot of total nitrite-nitrogen indicates a gradual decline in concentrations from 1975 to 1979. Concentrations averaged 0.04 mg/l in 1975, 0.03 mg/l in 1977, and 0.01 mg/l in 1979. Post 1979 concentrations remained fairly steady at an average annual concentration of 0.01 mg/l. The Seasonal Kendall's test indicated a downward trend in the concentration and transport records for ammonia-nitrogen and nitrite-nitrogen.

Regression analyses of ammonia-nitrogen and nitrite-nitrogen resulted in significant relationships. Positive slopes of the regression suggest that at higher flows there is a greater input of these two nutrients to Sherman Creek. The declining trends in concentration and transport could, therefore, be an artifact of a pattern of discharges. However, tests performed on the FACs suggest that some change other than streamflow has taken place, resulting in reduced inputs of ammonia-nitrogen and nitrite-nitrogen in Sherman Creek.

TABLE 18

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU FOR STATION WQN0243

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	*	*				
Total NH3-N+NH4-N	- S	- S	0.10	+ S	- S	OTHER
Total NO2-N	- HS	- HS	0.04	+ S	- HS	OTHER
Total NO3-N	*	*				
Total NO2-N+NO3-N	*	*				
Total INORG-N	*	*				

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
+ - Increasing trend/positive slope.
- - Decreasing trend/negative slope.

Assessment

Changes that occur in the county in the future are not expected to have a substantial impact upon the surface streams of the area. The rural population will continue to grow at a high rate. Growing at the overall rate experienced between 1970 and 1980, it will take 31 years for the population density to double to 124 persons per square mile--less than that of Adams County today. Growing at the 1970-80 rate, the density in Perry County will reach 200 persons/sq. mi. in 2062. If the bulk of this growth occurs on large-lots with self-contained sewage systems, there is some possibility that ground-water sources will be degraded over time.

One other possible source of contamination of surface and ground waters is from the manure produced by broiler operations if that sector maintains its recent rate of growth. The manure concentration ratio shows a slight upward trend. At this time, however, it is of the same order of magnitude as those of all of the other counties, excepting Lancaster (Figure 11). Further, estimated animal waste from all species in 1982 was the lowest of all the counties. In all probability, substantial natural assimilative capacity remains before the system is stressed.

Past land use activities have not substantially impacted the surface waters of the Sherman Creek watershed. Based on the land use data used for this study period, the declining trends in the statistical analysis of ammonia-nitrogen and nitrite-nitrogen can not be attributed to any changes in historical land use activities.

York and Adams Counties & West Conewago Creek and Codorus Creek Watersheds

County Summaries

York County

In terms of total land area and population York County is a close second to Lancaster. In terms of forest cover, the amount of land suitable for cropping and amount of cash receipts from the sales of agricultural products, York and Adams Counties are very similar (Tables 6 and 7). Like the City of Lancaster, the City of York is the central city of an MSA.

The county leads the state in the production of wheat, barley and soybeans and was second in corn for grain and potatoes (PA Agricultural Statistics Service, 1985, p. 5). Even so, its livestock sector was twice the size of the crop sector in terms of cash receipts from sales.

In the study area, York County leads all the other counties except Lancaster in cattle and hog production. It ranks second to Adams County in poultry. Overall, its livestock sector is the second largest only to Lancaster. As a consequence, York is second to Lancaster in the amount of manure generated (Figure 10) in the study area.

York County has a shrinking agricultural sector. Land in farms has declined by 25,000 acres since 1969. Starting with the second largest livestock base (total animal units--all species) among the six counties, that base has grown more slowly, both in absolute and percentage terms, than any of the other counties. The manure concentration ratio shows a declining trend overall and was the lowest of any of the counties in 1982. The slight upturn in the ratio in 1982 reflects a small increase in total animal units and a small decline in cropland between 1978 and 1982.

Adams County

Adams is primarily a rural county. Its population increased by a substantial percentage between 1970 and 1980, but the growth was entirely in the rural population. While the percentage increase was substantial, it arose from the relatively small 1970 population base.

Adams County is part of the York Metropolitan Statistical Area. The population density of the county, 131 persons per square mile, is well below that of the state and the average for the study area (Table 3). Much of the new residential construction is on multi-acre lots by persons commuting to jobs in York, Hanover, Carlisle, Camp Hill, Harrisburg, Pa., and as far as Washington, D.C.

More than half of the county is farmland (Figure 5). Cash receipts from crops and livestock is the most nearly balanced of any of the counties (Table 7). Adams County is the center of apple production, producing half of the Commonwealth's total crop (PA Agricultural Statistics Service, 1985, p. 59). The abundance of land suitable for cropping is indicated by the relatively high suitability ratio and relatively small amount of forested area (Table 6).

Livestock provided about 60 percent of the cash receipts of the farm sector. Aside from an increase in laying hens in 1982, the animal population have been essentially unchanged over the period studied. Moreover, the number of animal units for all species are relatively modest. Thus, the quantity of animal wastes produced per acre per year is fairly constant and at the moderate rate of about four tons per acre per year. In absolute terms, the county ranks fourth among the study counties in the tons of manure produced per year.

Watershed Summaries

Two of the tributary watersheds of the Susquehanna River that traverse York and Adams Counties were studied. West Conewago Creek has its headwaters in Adams County with the middle and lower reaches in northern York County. South of West Conewago Creek is Codorus Creek, located within York County.

West Conewago Creek

West Conewago Creek flows northeastward from its headwaters in the South Mountain Section of the Blue Ridge Province to its junction with the Susquehanna River, fourteen miles southwest of Harrisburg. Most of the West Conewago Creek watershed is located in the Triassic Lowland Section of the Piedmont Province. The stream drops from an altitude of 1,440 feet at the headwaters to 259 feet at the mouth. The main channel is characterized by a narrow valley having steep slopes and high hills in the upper reach, a broad valley having mild slopes and rolling hills in the middle reach, and a narrow valley having moderate to steep slopes and mountains in the lower reach.

The watershed encompasses approximately 515 square miles. In 1973, land uses consisted of 54 percent in agriculture, 34 percent in forest, and 2.2 percent in urban. Generally, agricultural lands occupy the broad valleys and rolling hills in the central portion of the watershed and the terrain around the Little Conewago Creek in the south. The upper and lower reaches of the basin contain steep slopes unsuitable for farming and are primarily forested, forming a buffer between agricultural lands and the stream. Major urban areas are located around Hanover in the south and the suburbs of York in the southeast. Small rural communities are scattered throughout the watershed.

Thirteen municipal wastewater management systems are currently located in the West Conewago Creek watershed and have a total average design discharge of 6.1 mgd (Table 19). The combined discharges of non-public systems is about 0.38 mgd. Most municipal STPs lack phosphorus removal and nitrification processes in their waste treatment operations.

TABLE 19

WEST CONEWAGO CREEK WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL		OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
Hanover Boro STP	2.200			6/74	NEW
Dover Twp. S. A.	1.750			11/73	NEW
New Oxford M. A.	0.825	P	N	4/80	NEW
McSherrystown Boro	0.420			4/74	NEW
Dover Boro M. A.	0.150			6/75	NEW
East Berlin M. A.	0.150			6/75	NEW
Reading Twp. M. A.	0.130			3/78	NEW
York Springs M. A.	0.120			10/82	NEW
Lewisberry Boro	0.100	P		1/86	NEW
Lake Meade M. A.	0.080	P	N	3/82	NEW
York Haven S. A.	0.080	P		?	?
Arendtsville M. A.	0.070	P		4/74	NEW
Possum Valley S. A.	?			7/86	NEW

Original issue dates of NPDES permits and data from GICS indicate that municipal STPs in the West Conewago Creek watershed began operating at or above the secondary level of treatment since the passage of the Clean Water Act of 1972. Six STPs were operating within three years of the Clean Water Act while additional STPs were installed during later years.

A review of NPDES permitted industrial waste dischargers and associated SIC codes revealed one industry, W. E. Bittinger Company (2037), as a nutrient generator. The W. E. Bittinger Company discharges an average of 278,000 gallons a day of food processing wastes. The wastes are screened and applied to the land through spray irrigation and not discharged directly to the stream.

Codorus Creek

Codorus Creek drains a 278 mi^2 area and flows 48 miles northeastward from its headwaters to its confluence with the Susquehanna River. The Codorus Creek watershed lies within the Piedmont Plateau Province and is characterized by a broad valley having moderate slopes and rolling hills in the upper and middle reaches. The lower reach contains a narrow valley having moderate to steep slopes.

Land use in the Codorus Creek watershed consisted of 53.4 percent in agriculture, 26.6 percent in forests, and 4.5 percent in urban as of the early 1970's (Takita, 1977). Urban areas have increased noticeably in the suburbs around York and Hanover along major roadways radiating from these two urban centers. The intensity of urban growth has not only been in residential uses but also in commercial and industrial developments. This area undergoing urbanization occupies the lower portion of the watershed restricting the bulk of agricultural and forest lands to the broad ridgetops of the upper watershed. As a result, most agricultural runoff enters Codorus Creek in the upstream portion of the drainage basin.

Six municipal wastewater management systems are in the watershed and contribute a total average design discharge of 43.4 mgd (Table 20). Sixty percent of the treated wastes originates from the York City STP. With the exception of New Freedom's STP, most municipal sewage treatment systems in the watershed lack phosphorus removal and nitrification processes in plant operations. The Springettsbury Township STP is located downstream of the water quality station utilized in the analyses, but was included due to its relatively large contribution of treated wastes to the Codorus Creek.

TABLE 20

CODORUS CREEK WATERSHED
PUBLIC SEWAGE TREATMENT FACILITIES

FACILITY LOCATION	AVERAGE DESIGN FLOW (MGD)	NITRIFICATION AND PHOS REMOVAL		OPERATION DATE OF UPGRADE	TYPE OF UPGRADE
York City S.A.	26.0	P		6/81	ICT*
Springettsbury Twp.	15.0		N	6/74	NEW
New Freedom Boro	1.35	P	N	6/77	NEW
Penn Twp. A.	0.42			3/83	ICT*
Spring Grove Boro	0.33			12/85	NEW
Glen Rock S.A.	0.30			2/81	NEW

* ICT-Increased capacity & treatment

A review of NPDES permitted industrial waste dischargers and associated SIC codes revealed that 5 of 33 industrial dischargers are considered nutrient generators (Table 21). The majority of the nutrient generating firms in the watershed are activities food processing and other agricultural related activities.

TABLE 21

CODORUS CREEK WATERSHED
FIRMS CONSIDERED NUTRIENT GENERATORS

FACILITY NAME	SIC CODE
Agway Inc./ York	2879
Rutter's Dairy	2026
Cole Steel/ North	3471
National Can Corp.	3411
Hanover Brands	2034

Analysis of Water Quality Data

<u>West Conewago Creek Watershed</u>

Data from one water quality station were examined for trends in nutrient concentrations and loads in West Conewago Creek. Station WQN0210 represents 510 square miles of a agricultural and forested watershed.

Graphical and statistical procedures were performed on the concentration record (1973-1986) and transport record (1973-1985). The transport record was constructed utilizing mean daily discharge data at USGS gaging station (01574000) located at the same site as the water quality network station.

During the 1973-1986 monthly sampling period, total phosphorus averaged 0.24 mg/l and ranged from 0.07 mg/l to 1.7 mg/l (Appendix A.6). Average total load for the period was 876 lbs/day or 1.7 lbs/day per mi^2.

Time series plots of total phosphorus revealed a regular seasonal cycle in concentration with elevated values occurring during late summer to early fall. A visual comparison of the mean daily discharge time series to that of phosphorus did not indicate any evidence that concentration fluctuations were the result of changes in the flow pattern. The transport time series did not exhibit any apparent trends.

Statistical tests on the phosphorus time series data indicated an increasing trend in concentration but no trend in the transport record (Table 22). Results of the FAC procedure indicated that some process change other than flow has contributed to rising phosphorus concentrations in West Conewago Creek.

Total inorganic nitrogen averaged 1.95 mg/l ranging from 0.04 mg/l to 4.6 mg/l. Total nitrate-nitrogen accounted for 93 percent of the inorganic portion. Average daily load of inorganic nitrogen was 3.17 tons or 12.4 lbs/mi^2 for the period of study.

TABLE 22

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU
FOR STATION WQN0210

Parameter	CONC Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	+ S	*	0.02	+ S	+ S	OTHER
Total NH3-N+NH4-N	- HS	- HS	0.03	+ S	- HS	OTHER
Total NO2-N	- HS	- HS	0.14	+ HS	- HS	OTHER
Total NO3-N	*	*		*		
Total NO2-N+NO3-N	*	*		*		
Total INORG-N	*	*		*		

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
+ - Increasing trend/positive slope.
- - Decreasing trend/negative slope.

Time series plots of the various inorganic forms of nitrogen were visually evaluated for trends. Concentrations of total ammonia-nitrogen were low and fairly constant with values less than 0.03 mg/l during much of the sampling period and showed little response to fluctuations in streamflow. The plot of total nitrite-nitrogen revealed decreasing concentrations from late 1976 to mid 1979. Even though the data exhibits a fair amount of variability, 71 percent of the concentration values remained at or below 0.02 mg/l after 1978, whereas only 9 percent of the values were equal or less than 0.02 mg/l before 1979. Nitrate-nitrogen showed no trends.

Statistical tests showed declining trends in ammonia-nitrogen and nitrite-nitrogen concentration and transport records

(Table 22). Results of the tests on the FACs suggest that some change has taken place due to causes other than discharge, resulting in reduced inputs of ammonia-nitrogen and nitrite-nitrogen to West Conewago Creek.

Codorus Creek Watershed

Data from two water quality stations were examined for trends in nutrient concentrations and loads on Codorus Creek. The upstream station, WQN0209, is located above the City of York on the South Branch of the Codorus Creek and represents 117 mi^2 of a primarily agricultural watershed. Station WQN0207 is located downstream of York City and surrounding urbanized areas and covers 265 mi^2 or 95 percent of the watershed.

Graphical and statistical procedures were performed on the concentration (1973-1986) and transport records (1973-1984) at both stations. Transport records were constructed utilizing mean daily discharge data from USGS gaging station 01575000 for WQN0209 and station 01575500 for WQN0207. Gaging station 01575000 is located at the sampling location WQN0209.

During the 1973-1986 monthly sampling period, total phosphorus averaged 0.14 mg/l or 122 lbs/day per mi^2 at the upstream station (Appendix A.7). The downstream station averaged 0.60 mg/l or 780 lbs/day per mi^2. The increased concentration values recorded at the downstream station as compared to the upstream station is indicative of nutrient enriching conditions in the Codorus.

Time series plots of total phosphorus did not reveal any visual trends in concentration or loads at either station. Concentrations of total phosphorus at station WQN0209 were fairly constant and exhibited little response to fluctuations in mean daily discharge. Most values varied between 0.04 mg/l to 0.2 mg/l. At the downstream site, phosphorus concentrations were more variable with values between 0.02 mg/l and 1.0 mg/l. However, beginning in 1984, phosphorus concentrations remained fairly constant staying below 0.5 mg/l. Considering that the average concentration is 0.6 mg/l, there should be a declining trend in total phosphorus.

Statistical tests on the data showed declining trends in concentrations and loads at the downstream site (WQN0207). No trends in phosphorus concentrations or loads were found at the upstream site. The test of FACs indicated that some process change other than flow has contributed to declining phosphorus concentrations in the lower reach of Codorus Creek.

Total inorganic nitrogen at the upstream and downstream stations averaged 3.7 mg/l and 4.3 mg/l, respectively (Appendix A.7). Mean ammonia-nitrogen concentration was much higher at station WQN0207 (1.1 mg/l) as compared to station WQN0209 (0.12 mg/l).

For station WQN0209, ammonia-nitrogen and nitrite-nitrogen time-series plots exhibited very little variability in concentration values during the 1973 to 1986 period. Most values of ammonia-nitrogen varied between 0.01 mg/l to 0.03 mg/l while most nitrite-nitrogen values varied between 0.02 mg/l to 0.04 mg/l. Trends in the concentration and transport time series were not apparent for these two parameters. Concentrations of ammonia-nitrogen and nitrite-nitrogen were much higher and more variable at the downstream station (WQN0207) than at the upstream station (WQN0209). Beginning in 1980, ammonia-nitrogen values became more variable ranging anywhere from 0.05 mg/l to 5.6 mg/l, whereas before 1980, concentration values remained below 2.0 mg/l. Nitrite-nitrogen concentrations were also much higher at the downstream station and exhibited a time series pattern similar to that of the upstream station.

Total nitrate-nitrogen concentration showed some relation to streamflow. However, concentrations varied more sharply during seasonal cycles than during flow fluctuations. High nitrate-nitrogen concentrations occurred late spring through early fall while lower nitrate-nitrogen concentrations occurred late fall through early winter. Since 1982, the lower concentrations expected from late fall through early winter have gradually increased thus reducing the range of concentrations within each seasonal cycle. Although the nitrate-nitrogen time series followed the same pattern as at the upstream station, the monthly concentration values generally were slightly less.

Statistical tests of the nitrogen data showed increasing trends in concentration for three parameters (organic nitrogen, NO_3-N, and NO_2-N+NO_3-N) at the upstream station (WQN0209) (Table 23). Results of the FAC tests indicated that some process change other than flow have increased concentration to the reaches of Codorus Creek. The nitrite-nitrogen data shows a decreasing trends in concentration but not in load. The ammonia-nitrogen data shows both decreasing trends in concentration and load. The regression of both nitrite-nitrogen and ammonia-nitrogen on streamflow was not significant, therefore, the FAC's were not tested.

Trend testing results of the nitrogen data at the downstream station (WQN0207) differed from that of the upstream station (WQN0209). The ammonia-nitrogen data indicates of an increasing trend in concentration and load (Table 23). The FAC data showed a highly significant upward trend in ammonia-nitrogen. This suggests some change has taken place, resulting in greater inputs of ammonia-nitrogen to the Codorus Creek.

Tests on total inorganic nitrogen and nitrite-nitrogen time series from the downstream station (WQN0207) resulted in upward trends in concentration but no apparent trends in loads. However, the analyses of the flow-adjusted-concentrations indicated downward trends in the two parameters. The opposing trends suggest that the upward trend in the concentration time series may be a consequence of flow conditions which has masked the effect of other processes contributing to reduced inputs of inorganic nitrogen and nitrite-nitrogen to the stream.

TABLE 23

TREND TESTING RESULTS BASED ON SEASONAL KENDALL'S TAU FOR STATIONS WQN0207 AND WQN0209

WQN0207 (Downstream station)

Parameter	CONCEN Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	- HS	- HS	0.04	+ S	- HS	OTHER
Total NH3-N+NH4-N	+ S	+ HS	0.41	+ S	+ HS	OTHER
Total NO2-N	+ S	*	0.02	- S	- HS	OTHER
Total NO3-N	*	*				
Total NO2-N+NO3-N	*	*				
Total INORG-N	+ HS	*	0.03	- S	- S	OTHER

WQN0209 (Upstream station)

Parameter	CONCEN Slope	LOAD Slope	REGRESSION R^2	REGRESSION Slope	FAC Slope	FAC Process
Total PHOS	*	*				
Total NH3-N+NH4-N	- HS	- HS		*		
Total NO2-N	- HS	*		*		
Total NO3-N	+ S	*	0.19	+ HS	+ S	OTHER
Total NO2-N+NO3-N	+ S	*	0.19	+ HS	+ S	OTHER
Total INORG-N	+ S	*	0.19	+ HS	+ S	OTHER

HS-Highly Significant; S-Significant; *-Not Significant
Flow-Trends in concentration or load result from trends in discharge
Other-Trends in concentration of load result from processes other than discharge
+ - Increasing trend/positive slope.
- - Decreasing trend/negative slope.

Assessment

The evaluation of the water quality data indicates the occurrence of nutrients in West Conewago Creek may be due to agricultural activities. The watershed contains more than half of its land area in agriculture and ranks second in livestock population of the watersheds investigated to that of the Conestoga River watershed (U.S. Bureau of the Census, 1969, 1974, 1978, 1982). The contribution of nutrients from STPs and industrial point sources are relatively insignificant, given three small total combined discharge.

The analysis of nutrient data for West Conewago Creek indicates a rising trend in total phosphorus concentration and declining trends in ammonia-nitrogen and nitrite-nitrogen (Table 22).

One possible explanation of the rising trend in phosphorus is as follows. Production of livestock on larger and fewer farm units in animal feedlots or barn yards in close proximity to streams may be viewed as "agricultural point sources" (Porter, 1975). In the Conewago Creek watershed, the livestock populations have remained fairly constant but the type of livestock has changed to animals that produce higher nutrient concentrations in their wastes (Table 5 and Figures 5, 6, 7, 8). This may be a cause of increasing phosphorus concentrations in the West Conewago Creek where feeding and holding areas are located near stream channels.

If agricultural "point sources" are influencing nutrient concentrations in West Conewago Creek, a similar increase in nitrogen concentrations would be expected. However, statistical analyses indicate that decreasing trends in ammonia-nitrogen and nitrate-nitrogen are occurring. This apparent contradiction may be the result from two processes: the complex interactions of chemical, physical, and biological processes acting in the nitrogen cycle on the shrinking agricultural sector and declining trend in the manure concentration ratio.

The surface waters of the Codorus Creek watershed suffer from nutrient enrichment problems associated with domestic sewage and industrial waste discharges, urban runoff, and agricultural sources. Water quality surveys conducted by the Bureau of Water Quality Management (1972, 1977, 1980, 1982, 1986) show many degraded stream segments throughout the watershed.

Based on average concentrations and trends, inorganic forms of nitrogen seem to be more of a problem than total phosphorous. The presence of high ammonia-nitrogen concentrations at the downstream station indicates pollution from raw sewage. Ammonia-nitrogen is unstable in aerated water and is generally considered as a nutrient located near the discharge source. The relative close proximity of the water quality station to the City of York suggests that urban runoff and the York Municipal STP are the sources of these nutrients.

Agricultural runoff and discharges from the activities of a growing population and economy also contribute nutrients to the streams of the watershed. The general nutrient enrichment problems seen in the lower reaches of Codorus Creek are probably the accumulated effect of upstream discharges, agricultural runoff, York Municipal STP discharges, urban runoff and industrial point sources.

CONCLUSIONS

Monthly water quality data from ten stations in seven watersheds of the Lower Susquehanna River Basin were analyzed for trends in phosphorus and nitrogen concentration and loads. The data generally represents a period from 1973 to 1986. Changes in land use activities in six counties were also investigated to make land use/nutrient trend comparisons and identify any significant relationships.

Time series plots and the nonparametric Seasonal Kendall Tau test trends were utilized to detect the presence of monotonic trends or changes in nutrient concentrations and loads. Where significant trends in concentration or load were detected, regression analysis was used to estimate the effect of flow on those trends. The Seasonal Kendall Tau test was applied to the residuals (FACs) from the regression to determine whether the trends were due to flow or other causes. Ideally, instantaneous discharges should have been used in the regressions instead of mean daily values which may have resulted in better correlations. The analysis was hampered by the lack of instantaneous discharge data associated with the water quality data. Thus, the collection of ancillary data (i.e. instantaneous discharge, temperature, conductivity and pH) at the time of sample collection should be a part of all sampling programs.

During the period of study, the study area has experienced major changes in population and land use. Farmland has been converted to suburban uses. Changes in farming practices have resulted in more intense use of agricultural land and increased the amount of manure generated and applied to the land. These changes in man's activities have affected phosphorus and nitrogen concentrations and loads in some of the streams investigated. The results of this investigation indicate that nonpoint as well as point sources have a major influence on certain segments of the streams evaluated.

The Conodoguinet Creek is primarily affected by point sources. Changes in the water quality occurred simultaneously during a period of STP installations and upgrades. The Carlisle STP probably had the greatest impact on observed trends in nutrients. Decreasing trends occurred in phosphorus, ammonia-nitrogen, and nitrite-nitrogen concentration and load. Increasing trends occurred in nitrate-nitrogen and total inorganic nitrogen concentrations.

Water quality data from Yellow Breeches Creek suggested the absence of major degrading influences and limited impacts from man's activities due to the large proportion of the watershed in forest areas. Remaining areas consisted of low intensity agriculture and medium density residential. All nutrients showed declining trends in concentration or load; however, these trends can not be attributed to any changes in land use based on available data.

The implementation of phosphorus reduction and removal techniques at STPs in the Swatara Creek watershed coincided with decreasing trends in phosphorus load. Streams draining agricultural areas of the watershed exhibited increasing trends in nitrate-nitrogen and inorganic nitrogen concentrations. This suggests that point and nonpoint source contributions play an important role in nutrient loads to Swatara Creek.

The highest concentrations and loadings of nutrients were recorded on the Conestoga River, largely because of intense agricultural activities. The most dominant agricultural activities are the growth in livestock and increased manure production. From 1969 to 1982 annual manure production increased from 10 to 14 tons/acre in Lancaster County as compared to 5 to 6 tons/acre in the remaining counties of the study area. The Conestoga River also receives 50 percent of Lancaster County's wastewater discharges from STPs.

In the Conestoga Watershed, two stations were included in trends analyses: the upper station represented inputs from agricultural activities while the lower station represented additional inputs from the City of Lancaster. The trends in the various nitrogen species at the lower station were flow related. However, decreasing trends in phosphorus concentration and load resulted from processes other than flow. At the upper station, upstream of Lancaster City, statistically significant decreasing trends were found in phosphorus, ammonia-nitrogen, and nitrite-nitrogen concentration and loads, but increasing trends occurred in nitrate-nitrogen and inorganic nitrogen.

The Sherman Creek watershed is characterized as a rural, mountainous region with small isolated areas of population and agricultural activities. As a result, the surface waters are relatively pristine. Only two parameters, nitrite-nitrogen and ammonia-nitrogen, exhibited trends and these trends indicated decreasing concentrations and loads resulting from processes other than flow. These trends can not be attributed to any changes in past land use activities.

The evaluation of the water quality data in the West Conewago Creek indicated the occurrence of nutrients may have resulted from agricultural activities. The contribution from municipal and industrial point sources is relatively insignificant. The nutrient data showed a rising trend in phosphorus concentration and declining trends in ammonia-nitrogen and nitrite-nitrogen. The declining trends in the nitrogen species may be the result of a shrinking agricultural sector and declining trend in the manure concentration ratio.

The surface waters of the Codorus Creek Watershed suffer from nutrient enrichment problems associated with domestic sewage and industrial waste discharges, urban runoff, and agricultural sources. Increasing trends in ammonia-nitrogen at the station downstream of urban influences opposes decreasing trends in ammonia-nitrogen from the station on the South Branch of Codorus. The increasing ammonia-nitrogen trend was probably due to a combination of point source discharges and urban runoff.

In summary, the total phosphorus concentration in the region shows a general downward trend while total inorganic nitrogen is trending upward. The results of statistical analyses indicate that the majority of the trends are due to processes other than that of flow. These processes are likely the result of man's activities.

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APPENDIX A.1

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATIONS WQN0213 AND WQN0240
IN THE CONODOGUINET CREEK WATERSHED

WQN0213

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	134	505	598	3992	306	81
PHOS, mg/l	148	0.17	0.12	1.33	0.13	0.02
NH3-N+NH4-N, "	138	0.14	0.11	0.72	0.11	0.01
NO2-N, "	140	0.04	0.03	0.18	0.03	<0.01
NO3-N, "	139	3.53	1.31	12.86	3.30	0.21
NO2-N+NO3-N, "	139	3.57	1.31	12.91	3.40	0.22
INORG-N, "	139	3.70	1.32	13.06	3.55	0.35
PHOS, tons/day	130	0.24	0.43	3.30	0.13	<0.01
NH3-N+NH4-N, "	121	0.17	0.27	2.58	0.10	<0.01
NO2-N, "	122	0.04	0.50	0.47	0.03	<0.01
NO3-N, "	122	4.21	5.03	36.2	2.58	<0.01
NO2-N+NO3-N, "	122	4.26	5.06	36.7	2.61	<0.01
INORG-N, "	122	4.42	5.29	39.3	2.71	0.16

WQN0240

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	123	682	1148	10648	340	92
PHOS, mg/l	139	0.17	0.18	2.00	0.13	0.02
NH3-N+NH4-N, "	140	0.11	0.11	0.91	0.08	0.01
NO2-N, "	141	0.03	0.02	0.18	0.03	<0.01
NO3-N, "	141	3.34	1.18	9.45	3.11	0.05
NO2-N+NO3-N, "	141	3.37	1.18	9.46	3.18	0.07
INORG-N, "	140	3.51	1.15	9.47	3.34	0.14
PHOS, tons/day	121	0.41	1.26	12.1	0.14	0.01
NH3-N+NH4-N, "	122	0.24	0.79	7.18	0.08	<0.01
NO2-N, "	122	0.07	0.14	1.20	0.04	<0.01
NO3-N, "	122	5.43	6.45	33.2	2.94	0.05
NO2-N+NO3-N, "	122	5.50	6.56	33.8	2.99	0.04
INORG-N, "	122	5.80	7.12	38.0	3.03	0.08

APPENDIX A.2

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATION WQN0212
IN THE YELLOW BREECHES CREEK WATERSHED

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	126	227	289	1800	237	79
PHOS, mg/l	136	0.11	0.17	1.80	0.08	0.03
NH3-N+NH4-N, "	134	0.06	0.05	0.24	0.05	0.01
NO2-N, "	134	0.02	0.01	0.08	0.02	<0.01
NO3-N, "	134	1.88	0.50	4.18	1.81	0.34
NO2-N+NO3-N, "	134	1.89	0.50	4.20	1.82	0.37
INORG-N, "	134	1.96	0.52	4.32	1.88	0.44
PHOS, tons/day	119	0.11	0.20	1.28	0.05	0.01
NH3-N+NH4-N, "	115	0.06	0.10	0.73	0.03	<0.01
NO2-N, "	115	0.02	0.02	0.20	0.01	<0.01
NO3-N, "	115	1.52	1.21	8.26	1.20	0.12
NO2-N+NO3-N, "	115	1.53	1.23	8.46	1.21	0.13
INORG-N, "	115	1.60	1.31	9.19	1.26	0.15

APPENDIX A.3

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR
1973-1986 OBSERVATIONS AT STATION WQN0211
IN THE SWATARA CREEK WATERSHED

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	134	505	598	3992	306	31
PHOS, mg/l	148	0.25	0.80	9.64	0.13	0.02
NH3-N+NH4-N, "	139	0.14	0.11	0.72	0.11	<0.01
NO2-N, "	140	0.04	0.03	0.17	0.03	<0.01
NO3-N, "	139	3.53	1.31	12.86	3.30	0.21
NO2-N+NO3-N, "	139	3.57	1.31	12.91	3.39	0.22
INORG-N, "	139	3.71	1.32	13.06	3.55	0.35
PHOS, tons/day	103	0.60	1.64	14.62	0.20	0.05
NH3-N+NH4-N, "	102	0.46	1.00	8.95	0.19	<0.01
NO2-N, "	103	0.10	0.19	1.65	0.05	<0.01
NO3-N, "	103	6.97	7.64	52.8	4.63	0.29
NO2-N+NO3-N, "	103	7.08	7.79	54.4	7.08	0.33
INORG-N, "	102	7.53	8.69	63.4	4.77	0.40

APPENDIX A.4

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATIONS WQN0205 AND WQN0231
IN THE CONESTOGA CREEK WATERSHED

WQN0205 (Upstream station)

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	147	406	538	4270	250	46
PHOS, mg/l	154	0.28	0.28	3.0	0.24	0.06
NH3-N+NH4-N, "	144	0.25	0.93	11.0	0.12	0.01
NO2-N, "	145	0.06	0.04	0.35	0.06	<0.01
NO3-N, "	145	6.73	2.01	11.6	6.60	0.39
NO2-N+NO3-N, "	145	6.80	2.00	11.7	6.67	0.46
INORG-N, "	145	7.05	2.16	17.3	6.83	0.90
PHOS, tons/day	144	0.29	0.59	5.30	0.15	0.03
NH3-N+NH4-N, "	134	0.32	1.23	13.0	0.09	<0.01
NO2-N, "	135	0.06	0.06	0.39	0.05	<0.01
NO3-N, "	135	7.06	8.55	70.5	4.13	0.58
NO2-N+NO3-N, "	135	7.12	8.59	70.9	4.22	0.59
INORG-N, "	135	7.44	8.98	73.1	4.28	0.59

WQN0231 (Downstream station)

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	147	510	670	5252	322	57
PHOS, mg/l	155	0.59	0.41	3.86	0.51	<0.01
NH3-N+NH4-N, "	145	0.57	0.69	5.5	0.40	0.02
NO2-N, "	145	0.17	0.17	1.56	0.13	<0.01
NO3-N, "	145	6.49	2.11	14.2	6.41	0.39
NO2-N+NO3-N, "	145	6.66	2.08	14.3	6.60	0.64
INORG-N, "	145	7.23	2.19	17.3	7.12	0.96
PHOS, tons/day	144	0.72	1.20	9.64	0.43	0.02
NH3-N+NH4-N, "	135	0.62	0.85	7.94	0.37	<0.01
NO2-N, "	135	0.16	0.14	0.98	0.13	<0.01
NO3-N, "	134	8.75	10.16	68.1	5.19	0.66
NO2-N+NO3-N, "	135	8.87	10.19	68.7	5.26	0.86
INORG-N, "	135	9.48	10.63	71.7	5.72	0.91

APPENDIX A.5

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATION WQN0243
IN THE SHERMAN CREEK WATERSHED

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	57	303	406	2712	166	31
PHOS, mg/l	62	0.06	0.05	0.33	0.05	0.01
NH3-N+NH4-N, "	63	0.05	0.06	0.46	0.05	0.01
NO2-N, "	63	0.02	0.02	0.11	0.01	<0.01
NO3-N, "	63	1.07	0.55	3.08	1.0	0.14
NO2-N+NO3-N, "	63	1.09	0.55	3.09	1.02	0.15
INORG-N, "	63	1.15	0.58	3.15	1.12	0.18
PHOS, tons/day	56	0.07	0.21	1.46	0.02	<0.01
NH3-N+NH4-N, "	57	0.07	0.20	1.46	0.02	<0.01
NO2-N, "	57	0.02	0.03	0.15	<0.01	<0.01
NO3-N, "	57	0.93	1.11	4.97	0.44	0.02
NO2-N+NO3-N, "	57	0.44	1.14	5.12	0.44	0.02
INORG-N, "	57	1.02	1.28	6.59	0.45	0.02

APPENDIX A.6

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATION WQN0210
IN THE WEST CONEWAGO CREEK WATERSHED

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	141	630	1253	8280	284	29
PHOS, mg/l	135	0.24	0.18	1.70	0.21	0.07
NH3-N+NH4-N, "	134	0.11	0.14	0.84	0.07	0.01
NO2-N, "	134	0.03	0.02	0.10	0.02	<0.01
NO3-N, "	134	1.82	1.09	4.38	1.78	0.02
NO2-N+NO3-N, "	134	1.84	1.09	4.40	1.82	0.02
INORG-N, "	134	1.95	1.13	4.57	1.90	0.04
PHOS, tons/day	128	0.44	1.34	11.7	0.12	0.03
NH3-N+NH4-N, "	127	0.23	0.68	5.62	0.04	<0.01
NO2-N, "	127	0.06	0.17	1.52	0.01	<0.01
NO3-N, "	127	2.88	4.76	39.3	1.15	<0.01
NO2-N+NO3-N, "	127	2.94	4.90	40.8	1.17	<0.01
INORG-N, "	127	3.17	5.44	44.6	1.21	<0.01

APPENDIX A.7

SUMMARY STATISTICS OF SELECTED PARAMETERS FOR 1973-1986
OBSERVATIONS AT STATIONS WQN0207 & WQN0209
IN THE CODORUS CREEK WATERSHED

WQN0207 (Downstream station)

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	132	311	501	4760	183	33
PHOS, mg/l	147	0.60	1.06	11.40	0.36	0.02
NH3-N+NH4-N, "	137	1.11	1.11	5.61	0.73	0.05
NO2-N, "	136	0.07	0.05	0.46	0.07	0.02
NO3-N, "	137	3.12	1.07	5.77	3.24	0.47
NO2-N+NO3-N, "	136	3.20	1.08	5.94	3.29	0.53
INORG-N, "	136	4.32	1.18	7.81	4.28	1.10
PHOS, tons/day	129	0.39	0.81	7.83	0.20	<0.01
NH3-N+NH4-N, "	118	0.50	0.41	2.97	0.40	0.03
NO2-N, "	118	0.52	0.08	0.72	0.03	<0.01
NO3-N, "	118	2.47	3.45	24.16	1.44	0.21
NO2-N+NO3-N, "	118	2.53	3.50	24.88	1.47	0.22
INORG-N, "	118	3.02	3.82	27.06	1.83	0.33

WQN0209 (Upstream station)

Parameter	Obs.	Mean	Stn Dev	Max	Med	Min
Flow, inst-cfs	132	125	238	2340	71	1.3
PHOS, mg/l	129	0.14	0.22	2.30	0.11	0.04
NH3-N+NH4-N, "	127	0.12	0.17	1.47	0.07	0.01
NO2-N, "	127	0.03	0.02	0.12	0.03	<0.01
NO3-N, "	127	3.55	0.85	5.48	3.63	1.07
NO2-N+NO3-N, "	127	3.58	0.85	5.50	3.66	1.10
INORG-N, "	127	3.70	0.84	5.57	3.77	1.17
PHOS, tons/day	120	0.06	0.21	1.90	0.02	<0.01
NH3-N+NH4-N, "	116	0.04	0.12	1.07	0.01	<0.01
NO2-N, "	117	0.01	0.03	0.29	0.01L	<0.01
NO3-N, "	117	1.13	1.85	16.55	0.67	<0.01
NO2-N+NO3-N, "	117	1.14	1.88	16.84	0.67	<0.01
INORG-N, "	116	1.18	2.00	17.92	0.65	<0.01

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